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AND

JOURNAL

OF THE

Mineralogical Society.

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ASSISTED BY A COMMITTEE OF COUNCIL.

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THE MINERALOGICAL SOCIETY

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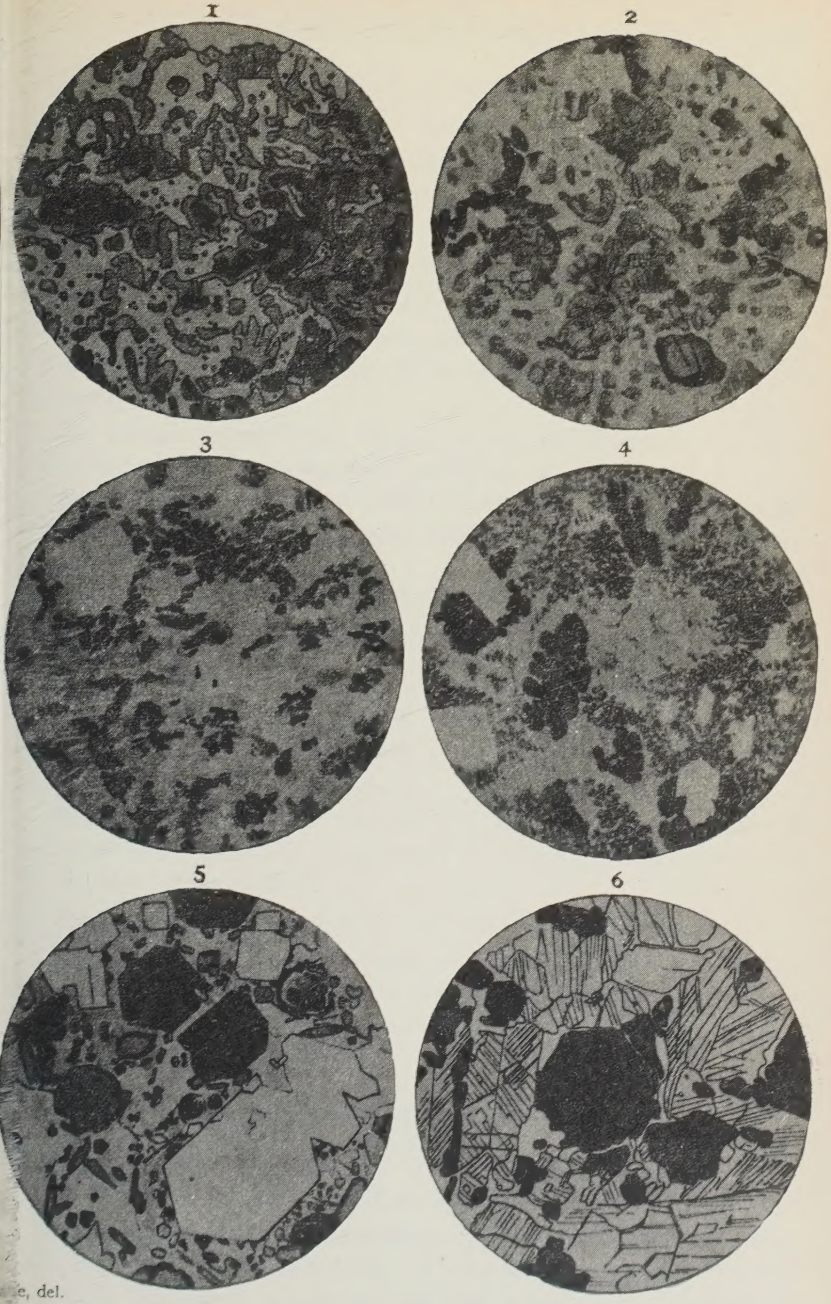

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G. T. Prior: Rocks from British East Africa.

[*Copied from original colour plate.*

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 25, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Mr. Alfred Prentice Young, Ph.D., F.G.S., was elected an Ordinary Member of the Society.

Messrs. Miers and Spencer were asked to report to the Council relative to the presentation and exchange list.

The President, General Secretary, and the Editor, in conjunction with Professor Church and Professor Miers, were appointed Editorial Committee for the Journal.

Mr. Spencer reported that he had indexed the literature relating to Mineralogy and Crystallography published in the United Kingdom during 1901, and had sent, on behalf of the Society, the index-slips to the Central Bureau of the International Catalogue of Scientific Literature.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 25, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Fourteen Members were present. The election of Dr. Young to the Ordinary Membership of the Society was confirmed.

The following paper was read:—

The Petrology of British East Africa: notes on the rock-specimens collected by Professor J. W. Gregory and Sir Harry Johnston respectively: by Mr. G. T. Prior (p. 228).

The paper was illustrated by specimens and micro-sections.

Professor Miers submitted a fragment of a statuette consisting chiefly of green mica: archaeologists agree that the workmanship is Roman, and Professor Miers suggested that the material may be one of the varieties of 'emerald' described by Pliny.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 10, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

The resignation of the Treasurership by Lieut.-Gen. McMahon, owing to failing eyesight, was announced. A vote was passed expressing deep sympathy with him in his trouble and high appreciation of the services which have been rendered by him to the Society. Mr. W. P. Beale was

elected Treasurer, and Lieut.-Gen. McMahon was elected to the Membership of Council thus vacated.

Mr. William B. Giles, F.I.C., was elected an Ordinary Member of the Society. The death of M. Moissenet, Honorary Member, was announced.

The Secretary submitted a list of changes which he recommended to be made in the Bye-laws of the Society.

Professor Judd, Foreign Secretary, was authorized to inform the Mayor of St. Just-en-Chaussée that the Society sympathizes with the project to establish a Memorial to the brothers Haüy in their native place.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 10, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Seventeen Members were present. The election of Mr. W. B. Giles to the Ordinary Membership of the Society was confirmed.

The following papers were read:—

1. On Meigen's method of discriminating Calcite and Aragonite: by Dr. A. Hutchinson.

Experiments had been made in order to discover the cause of the discrepancy in the results obtained by Meigen and Panebianco in the application of Meigen's method of discriminating calcite and aragonite [abstract, this vol., p. 206]. It was found that calcite, when treated with a boiling dilute solution of cobalt nitrate, only remains white or becomes yellow (as stated by Meigen) when the cobalt nitrate contains traces of iron, and that Panebianco's lavender-blue colour is only obtained when the cobalt nitrate is free from iron.

2. On the crystalline forms of Krennerite: by Mr. G. F. Herbert Smith (p. 264).

3. On the Gnomonic Projection: by the same.

4. On Volcanic dust fallen at Barbados: by Mr. G. T. Prior.

Specimens were exhibited, and the mineral constituents described, of the volcanic dust which fell in Barbados on May 7 and 8 after the eruption of the Soufrière of St. Vincent. The fact that the constituents are like those of a hypersthene-augite-andesite connects the eruptions with the Pacific rather than with the Atlantic volcanic chain.

5. On the non-existence of 'Kalgoorlite' and 'Coolgardite' as mineral species: by Mr. L. J. Spencer (p. 268).

6. On the crystalline forms of Liveingite: by Mr. R. H. Solly.

Mr. G. F. Herbert Smith exhibited and explained the new form of Three-Circle Goniometer constructed by Messrs. Troughton and Simms for the British Museum according to the plans suggested by him.

Specimens were exhibited by Messrs. Hutchinson, Prior, Spencer, and Solly in illustration of their papers.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 18, 1902.

Dr. Hugo Müller, FR.S., President, in the Chair.

The following Candidates were elected Ordinary Members of the Society:—Mr. Herbert Stanley Jevons, M.A., B.Sc., F.G.S.; Mr. Arthur Edward Ian Montagu Russell; Mr. Andrew Gibb Maitland, F.G.S.; Mr. John Smith Flett, M.A., D.Sc., F.R.S.E., F.G.S.; Mr. John Allen Howe, B.Sc., F.G.S.; and Mr. Frederic Philip Mennell, F.G.S. Professor A. D'Achiardi of Pisa was elected an Honorary Member of the Society.

The following dates were selected for the meetings of 1903:—February 3, March 24, June 9, November 17, the last to be the Anniversary Meeting.

Mr. J. H. Collins and Mr. H. L. Bowman were elected Auditors of the Balance Sheet for the year ending Dec. 31, 1902.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 18, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Twenty-four Members and one visitor were present.

The President nominated Mr. Barlow and Mr. Herbert Smith to act as scrutineers of the voting papers for the election of Officers and Council; the scrutineers reported that thirty-seven voting papers had been returned to the General Secretary, and that the List as nominated by the Council for the year 1902–3 was approved, namely:—

President. Hugo Müller, Esq., Ph.D., F.R.S.
Vice-Presidents. Prof. G. D. Liveing, M.A., F.R.S.
Prof. H. A. Miers, M.A., D.Sc., F.R.S.
Treasurer. W. P. Beale, Esq., K.C., F.G.S., F.C.S.
General Secretary. L. Fletcher, Esq., M.A., F.R.S.
Foreign Secretary. Prof. J. W. Judd, C.B., LL.D., F.R.S.
Editor of the Journal. L. J. Spencer, Esq., M.A., F.G.S.

Ordinary Members of Council.

The Earl of Berkeley, F.G.S.	F. W. Rudler, Esq., F.G.S.
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B. Kitto, Esq., F.I.C., F.G.S.	G. T. Prior, Esq., M.A., F.G.S.

The General Secretary read the following

ANNUAL REPORT OF COUNCIL.

The Balance Sheet for the year ending December 31, 1901, which will be issued with the next Number of the Journal, shows that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £650 8*s.* 9*d.*, and that the Liabilities amounted to £17 0*s.* 1*d.* The number of Life-Members on December 31, 1901, was fifty-two; the value of the Stock invested in the names of the Trustees of the Society was on that date £519 15*s.* 10*d.*

During the Session 1901–2 the Society has lost two Ordinary Members by resignation, and one Honorary Member by death; on the other hand, three Ordinary Members have been elected, and Professor A. D'Achiardi of Pisa has been added to the list of Honorary Members. The total number of Members is now 121; of these 102 are Ordinary Members and nineteen are Honorary Members.

Four meetings have been held during the year, all in London and (by kind permission) in the Apartments of the Geological Society, Burlington House.

One Number of the Journal, No. 60, published in May 1902, has appeared during the Session.

The Council has to congratulate the Society on its continued prosperity.

On the motion of the President, seconded by Mr. Scott, the Report was adopted. Votes of thanks to the retiring Auditor (Mr. Kitto) and to the Geological Society for the permission to meet in its Apartments were carried with acclamation.

The following alterations in the Bye-laws were proposed by the General Secretary in accordance with Bye-law 30.

Bye-law 4. 'The names of the Candidates shall be communicated to every Ordinary Member by the General Secretary.' To be withdrawn.

Bye-law 11. 'The names of all candidates proposed for Honorary

Membership shall be communicated by the General Secretary to every Member of the Council, and the election shall not take place until the expiration of four weeks after such communication.' To be withdrawn.

Bye-law 5. The words 'at a meeting held at least four weeks after the names of the Candidates have been so communicated' to be withdrawn.

Bye-law 10. The words 'and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the members present and voting,' to be added at the end of the Bye-law.

The proposal was carried.

The elections of Mr. H. S. Jevons, Mr. Arthur Russell, Mr. A. G. Maitland, Dr. J. S. Flett, Mr. J. A. Howe, and Mr. F. P. Mennell, to the Ordinary Membership of the Society were confirmed.

The President called the attention of the Meeting to the Memorial proposed to be erected to the brothers Haüy in their native place.

The following papers were then read:—

1. The crystalline forms of Proustite: by Mr. F. E. E. Lamplough (communicated by Professor Lewis) (p. 294).

2. On some minerals from Switzerland: by Professor W. J. Lewis (p. 291).

3. On Baumhauerite, Seligmannite, and a third mineral from Binn: by Mr. R. H. Solly.

4. On a Gnomonic Protractor: by Mr. G. F. Herbert Smith.

5. On the Molecular Volumes of some crystallographically similar minerals: by Mr. G. T. Prior (p. 217).

Owing to the lateness of the hour the following papers were taken as read:—

6. On Phonolitic Rocks from St. Helena and Ascension: by Mr. G. T. Prior (p. 256).

7. Crystalline forms of Carbides and Silicides of iron and manganese ('Ferro-manganese,' &c.): by Mr. L. J. Spencer (p. 296).

MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1901.

Receipts.	£ s. d.	£ s. d.
Balance from the year 1900		79 0 5
Subscriptions—(1) current	30 8 9	
(2) arrears	16 16 0	
		47 4 9
Entrance fees and compositions		17 17 0
Sale of publications by publishers	20 17 5	
,, from Stock (from 1898 inclusive)	4 17 1	
Miscellaneous receipts by Clerk in charge of Stock	2 11	
		25 17 5
Authors' extra copies		20 8 9
Donation from Professor Church for binding		10 0 0
Dividends on Stock		13 16 8
		£214 5 0

Payments.	£ s. d.	£ s. d.
Printing and Stationery		105 7 7
Illustrations		4 7 0
Binding		10 7 3
Attendant's Fee at Meetings		10 0
Clerk's Fee in charge of Stock (1900 & 1901)		2 2 0
Postage and Parcels		1 2 5
Commission on Cheques		1 0
Cover for Obligation Book	5 0	
Slips for Catalogue, Royal Society	3 2	
		8 2
Investments and Brokers' Commission		13 16 8
Balance at Bank	70 11 6	
,, in Office	5 11 5	
		76 2 11
		£214 5 0

Examined and compared with the vouchers, and found correct.

(*Signed*) BENEDICT KITTO } Auditors.
J. H. COLLINS }

Liabilities.	£ s. d.	£ s. d.
Debts owing—Printing	4 13 6	
Illustrations	6 3	
		4 19 9
Honorarium owing to Editor		10 10 0
Secretarial postage to Dec. 31, 1901		1 0 4
Attendant's Fee at Meetings to Dec. 31, 1901		10 0
Excess of assets over liabilities		633 8 8
		£650 8 9

Assets.	£ s. d.
Balance as above	76 2 11
Subscriptions unpaid	13 13 0
Stock in Consols £540 18*s.* 7*d.*, valued at £96	519 15 10
Dividend, January, 1902	3 10 0
Balance owing from Publishers from sale of Journal, 1901	37 7 0
	£650 8 9

The number of Life Members on December 31, 1901, was 52.

The Stock of Publications and the value of the Library are not included in the above assets.

(*Signed*) W. P. BEALE,
Hon. Treasurer.

June 30, 1902.

THE MINERALOGICAL MAGAZINE

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THE MINERALOGICAL SOCIETY.

No. 61. FEBRUARY, 1903. Vol. XIII.

The Chemical Composition and Optical Characters of Chalybite from Cornwall.

By A. Hutchinson, M.A., Ph.D.

Demonstrator of Mineralogy in the University of Cambridge.

[Read April 3, 1900.]

THE acquisition by the Cambridge Mineralogical Museum of a series of well-crystallized specimens of chalybite, raised within recent years from the mines in the neighbourhood of Camborne in Cornwall, afforded a favourable opportunity for an investigation of the chemical composition and optical characters of this substance. This seemed the more desirable since no analysis of the chalybite crystals from the Camborne district appears to have been published, and our knowledge of the optical characters of the substance is confined to some observations of Ortloff[1] on material containing large quantities of manganese carbonate from Wolfsberg in the Harz.

The specimen examined by Ortloff was of a pale yellow colour and had a cleavage angle of 72° 55′. Its composition was as follows:— $FeCO_3$, 77·32; $MnCO_3$, 17·04; $MgCO_3$, 5·42; $CaCO_3$, 0·86; total, 100·64. The refractive indices for D light, determined by means of

[1] Zeits. Phys. Chem., 1896, vol. xix, p. 215.

a prism of which the orientation is not stated, were: $\mu_o = 1{\cdot}93409$, $\mu_e = 1{\cdot}62185$.

The crystals used in the experiments described below were essentially combinations of the basal plane with a rhombohedron, and somewhat resembled octahedra in appearance[1]. The crystals measured from 5 to 10 mm. along the edges of the basal plane and were implanted on quartz. The faces were rough and uneven and did not lend themselves to a determination of the forms present.

On breaking up the crystals they yielded perfectly transparent cleavage fragments of a pale yellow colour. Some of the larger crystals were selected for the purpose of making into prisms, and from the remainder some 7 grams of pure fragments were obtained, and these were submitted to chemical analysis after determinations of the cleavage angle and specific gravity had been made.

Angle between the cleavage planes.—This was found to vary somewhat in the larger crystals, but a number of small fragments which gave good reflections yielded values lying between 73° 5′ and 73° 0½′. Mean value 73° 2½′.

Specific Gravity.—The specific gravity was determined by the aid of a pycnometer which contained 9·9782 grams of water at 17·7° C. Corrections were applied for weighing in air and for the temperature of the water. Two independent determinations made on the same sample gave the following results:—

Sp. gr. at 16·9°/4° = 3·938. (Weight of chalybite used, 5·6336 grams.)
„ „ 17·1°/4° = 3·936. („ „ 5·6207 „)

Chemical Analysis.—The mineral was completely soluble in hydrochloric acid. After oxidation, the iron and manganese were separated by a double precipitation with ammonium acetate. As traces of calcium and magnesium were found in the filtrate after the separation of the manganese, a special determination of these constituents was made. For this purpose iron and manganese were removed by precipitation as sulphides, the filtrate was evaporated to dryness in a platinum dish, ammonium salts were removed by ignition, and the calcium and magnesium estimated in the minute residue. One determination of carbon dioxide was made; it agreed very closely with the amount required to combine with the oxides.

[1] Compare fig. 3, p. 276, of Dana's 'System of Mineralogy,' 6th edit., 1892.

The results are exhibited in the following table:—

TABLE I.

	I.	II.	III.	IV.	V.
FeO	61·15	61·02	—	—	61·08
MnO	1·12	1·13	—	—	1·12
CaO	0·10	0·12	0·09	—	0·10
MgO	—	0·14	0·11	—	0·13
CO_2	—	—	—	38·19	38·19
					100·62

I. Weight of substance taken, 1·2027 gram. The iron and manganese were separated by ammonium acetate, the calcium precipitated as oxalate, and the presence of magnesium proved qualitatively in the filtrate.

II. Weight of substance taken, 0·9608 gram. The iron and manganese were separated as sulphides from the calcium and magnesium.

III. Weight of substance taken, 1·0973 gram. Calcium and magnesium alone determined after removal of the iron and manganese as sulphides.

IV. Weight of substance taken, 1·0238 gram. Carbon dioxide determined by absorption in potash.

V. Mean result.

If the quantities of the respective carbonates are calculated from the mean percentages of the oxides we obtain:—

$FeCO_3$	98·43
$MnCO_3$	1·82
$CaCO_3$	0·18
$MgCO_3$	0·26
	100·69

From the above results it is clear that this chalybite is nearly pure ferrous carbonate.

Optical Characters.—As there was not at my disposal an apparatus for grinding faces on crystals in any desired direction, the prisms employed for finding the refractive indices were cut arbitrarily by hand, and the orientation of the faces subsequently determined by measuring the angles that they made with the cleavage planes. The substance is easily ground down on a glass plate with fine emery, and an excellent polish can be given to it by means of rouge.

The prisms were set in each case to give minimum deviation for the ordinary ray, the deviation of the extraordinary ray was then determined

without altering the position of the prism, and finally the angle at which the light was incident on the first face of the prism was found. The measurements were made for lithium, sodium, and thallium light, incident on each of the two faces of the prism in turn.

Three prisms were prepared. The first (I) was cut with its refracting edge not far removed from parallelism with the optic axis, and its refracting angle was 42° 36½′. After a series of measurements had been made, this prism was re-ground and re-polished and its refracting angle reduced to 39° 13′. A new series of determinations was then made with this prism, which will be referred to in future as (I a). This prism was of a pale yellow colour, and its faces, though small, about 6 sq. mm. in area, were good and afforded perfect images of the slit. The second prism (II) was larger, the area of its faces being about 20 sq. mm.: it was made from very perfect material, and the faces were excellent. Its refracting angle was 53° 41′. The third prism (III), refracting angle 47° 45½′, was about the same size as the last, and made from equally good material, but the angle between the two cleavage planes used for finding the orientation of the artificial faces was abnormal, being 73° 48′ instead of 73° 2½′, and this discrepancy makes the true value of the principal extraordinary index as found by this prism a little uncertain.

Calling the prism faces P and S, and two of the cleavage planes R and R_1 respectively, the six angles between these four planes were measured. The values obtained for each prism are given in the following table:—

Table II.

Prism.	PS	PR	PR_1	SR	SR_1	RR_1
	° ′	° ′	° ′	° ′	° ′	° ′
I.	137 23½	65 58	120 6	131 52	93 24	106 59
I a.	140 47	63 26	119 13½	130 43	93 12	106 59
II.	126 19	80 33	125 49½	107 22	106 38½	73 3
III.	132 14½	176 0	77 5	51 41	69 3½	106 12

As the prisms were set to give the minimum deviation of the ordinary ray, the corresponding indices of refraction can be calculated from the formula $\mu_o = \dfrac{\sin\frac{A+D_o}{2}}{\sin\frac{A}{2}}$, where D_o is the deviation observed and A the refracting angle of the prism.

The velocity of the extraordinary wave and the direction of its normal in the crystal can be found by the method used by Glazebrook[1] in his verification of the law of double refraction in Iceland-spar. Let ϕ and ψ be the angles of incidence and of emergence respectively, ϕ' and ψ' the corresponding angles made by the wave-normal inside the prism, D_e the angle of deviation, and A the angle of the prism. Then we have

$$\phi + \psi = D_e + A \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\phi' + \psi' = A \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\tan \frac{\phi' - \psi'}{2} = \tan \frac{\phi' + \psi'}{2} \tan \frac{\phi - \psi}{2} \cot \frac{\phi + \psi}{2} \quad . \quad (3)$$

From these formulae, since D_e, A, and ϕ are known, ϕ' and ψ' can be calculated.

If, now, V (= 1) is the velocity of light in air and v its velocity in the crystal, we have

$$\frac{V}{v} = \frac{\sin \phi}{\sin \phi'} = \frac{\sin \psi}{\sin \psi'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The velocities v were calculated in each case from ψ and ψ' as well as from ϕ and ϕ'; the values thus obtained agreed very closely, and the mean of the two was taken as the true value. The following table (III) gives the values of D_o, D_e, ϕ, and $\frac{1}{v}$ for each prism.

From a knowledge of the angles made by the prism faces with the cleavage planes (Table II) we can calculate the angle between the optic axis and the wave-normal to which the velocity v corresponds. Then if v_o and v_e be the two principal wave-velocities, we have

$$v^2 = v_o^2 \cos^2 \theta + v_e^2 \sin^2 \theta \quad . \quad . \quad . \quad . \quad . \quad (5)$$

whence the principal extraordinary index, μ_e, can be found.

The method of calculating the value of θ is illustrated by the accompanying stereogram[2], which represents the case of prism I. The faces of the crystal are referred to a rectangular axial system OX, OY, OZ, and the crystal is so placed that the edge between the two cleavage planes RR_1 is parallel to the axis OZ, while the angles between Rr_1 and RR_1 are bisected by X and Y respectively. P is the pole of one face of the prism, S the pole of the other, while s is the pole at the other end

[1] Phil. Trans. Roy. Soc., 1880, vol. clxxi, p. 421.

[2] In the figure the faces P and S are slightly removed from their true position for the sake of clearness. In an accurate drawing K and L would lie very close together. OZ is normal to the paper at O.

Table III.

Prism.		Light incident on P.			Light incident on S.		
		Li.	Na.	Tl.	Li.	Na.	Tl.
I.	D_o	42° 41½′	43° 10½′	43° 35½′	42° 42½′	43° 11½′	43° 37′
	D_e	30 7	30 19½	30 32	30 9½	30 19½	30 32½
	ϕ	35 7	35 7	35 7	36 12	36 12	36 12
	$\frac{1}{v}$	1·6316	1·6356	1·6395	1·6328	1·6359	1·6401
I a.	D_o	38° 18′	38° 41½′	39° 4½′	38° 18′	38° 41′	39° 4½′
	D_e	27 28	27 38	27 47½	27 38	27 47	27 56½
	ϕ	38 47	38 47	38 47	40 1	40 1	40 1
	$\frac{1}{v}$	1·6326	1·6364	1·6399	1·6337	1·6371	1·6387
II.	D_o	60° 58½′	61° 45½′	62° 30′	60° 58½′	61° 45′	62° 28½′
	D_e	45 50	46 8	46 25½	44 45	45 5	45 21½
	ϕ	57 19¾	57 19¾	57 19¾	57 54½	57 54½	57 54½
	$\frac{1}{v}$	1·6785	1·6827	1·6867	1·6613	1·6661	1·6700
III.	D_o	50° 14′	50° 48′	51° 20½′	50° 13½′	50° 48′	51° 20′
	D_e	39 25	39 41	39 57½	40 3½	40 21	40 37
	ϕ	48 48	48 48	48 48	49 40¾	49 40¾	49 40¾
	$\frac{1}{v}$	1·6977	1·7021	1·7066	1·7063	1·7111	1·7156

of the normal on S, hence Ps represents the internal prism angle A. One end of the optic axis emerges at T, and the angle ZT can be calculated from the cleavage angle RR_1. From the spherical triangles PRX, Pr_1X, the angle PX can be found, for we have

$$\cos PX = \frac{\cos\frac{PR+Pr_1}{2}\cos\frac{PR-Pr_1}{2}}{\cos\frac{Rr_1}{2}}.$$

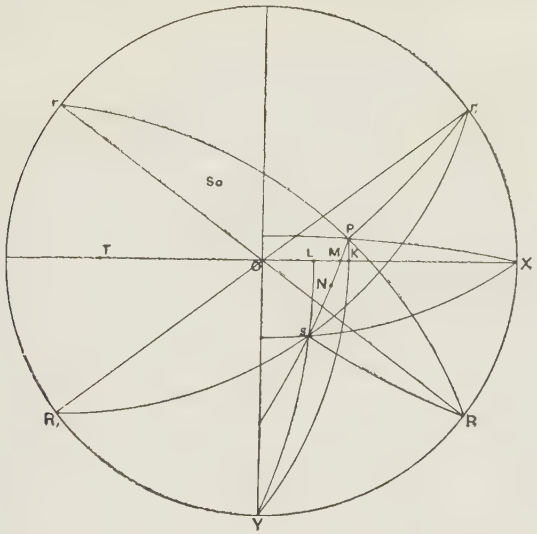
Similarly, we can find PY, sX, and sY.

The angle sM can be found by the formula

$$\cot sM = \frac{\sin PK}{\sin sL \sin Ps} + \cot Ps,$$

for we know $PK = PY - 90°$, $sL = 90° - sY$, and $Ps = A$. From the right-angled spherical triangle sLM, in which we know sL and sM,

we can find LM and the angle LM*s*. Again, from the right-angled spherical triangle *s*LX we can find LX and so obtain the value of $TM = 90° - LX + LM + ZT$. The position of emergence in P*s* of the wave-normal N is known, for we have determined the angles ϕ' and



ψ' which it makes with the normals to the prism faces. Hence from the spherical triangle TMN, in which the sides TM, MN, and the angle TMN are known, we can find the side $TN = \theta$, the angle between the wave-normal and the optic axis. The values calculated for θ are given in Table IV.

TABLE IV.

Prism.		Light incident on P.			Light incident on S.		
		Li.	Na.	Tl.	Li.	Na.	Tl.
		° ′	° ′	° ′	° ′	° ′	° ′
I.	θ	96 26½	96 27	96 27½	96 19⅓	96 19	96 18⅓
I a.	θ	95 43½	95 44	95 45	97 10	97 9⅓	97 8½
II.	θ	60 38½	60 42½	60 46½	66 21½	66 17	66 13
III.	θ	54 26¼	54 24	54 22	51 58	52 0	52 2

The following table (V) contains the values of μ_o and of μ_e obtained from each prism according as the light was incident on P or on S.

Table V.

Prism.	Light incident on face.	μ_o			μ_e		
		Li.	Na.	Tl.	Li.	Na.	Tl.
I.	P	1·8648	1·8733	1·8807	1·6291	1·6331	1·6370
	S	1·8651	1·8736	1·8811	1·6303	1·6335	1·6377
	Mean	1·8649	1·8734	1·8809	1·6297	1·6333	1·6373
I a.	P	1·8655	1·8734	1·8812	1·6306	1·6344	1·6379
	S	1·8655	1·8733	1·8812	1·6307	1·6340	1·6376
	Mean	1·8655	1·8733	1·8812	1·6306	1·6342	1·6377
II.	P	1·8643	1·8724	1·8801	1·6304	1·6340	1·6375
	S	1·8643	1·8723	1·8798	1·6295	1·6336	1·6368
	Mean	1·8643	1·8724	1·8799	1·6299	1·6338	1·6371
III.	P	1·8642	1·8722	1·8798	1·6281	1·6310	1·6344
	S	1·8641	1·8722	1·8797	1·6275	1·6310	1·6344
	Mean	1·8642	1·8722	1·8798	1·6278	1·6310	1·6344

It will be seen that the results exhibit a satisfactory degree of concordance; those yielded by prism II are probably nearest to the truth.

Note on a connexion between the molecular volume and chemical composition of some crystallographically similar minerals.

By G. T. Prior, M.A., F.G.S.
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[Read June 18, 1901, and November 18, 1902.]

THE molecular volumes of the members of an isomorphous group of minerals in general show an approach to equality. In other words, minerals having an analogous chemical composition show not only closely related crystalline forms, but have also approximately equal molecular volumes. Many years ago J. D. Dana[1] endeavoured to show that a simple relationship as regards molecular volume also subsisted in the case of various minerals which were closely related crystallographically, although unlike chemically. He concluded that in these cases the similarity in form depended solely on the relationship in molecular volume, and had nothing whatever to do with the chemical composition.

In the case of many of these minerals, however (more particularly those showing the closest crystallographic similarity), it is possible to discover a chemical relationship, although it is not one of so intimate a nature as that which connects the members of the ordinary isomorphous groups. This relationship depends on the fact that the chemical formulae of the minerals showing close crystallographic similarity and approximately equal molecular volumes are of the same form and contain approximately the same number of atoms, although they may not represent salts of the same acid or salts of metals having the same valencies. As examples of 'isomorphous' minerals of this kind we have the often-cited case of

Calcite, $CaCO_3$, (V = 37)[2],
Sodium nitrate, $NaNO_3$, (V = 40),

and of the felspars

Albite, $NaAlSi_3O_8$, (V = 100),
Anorthite, $CaAlAlSi_2O_8$, (V = 100).

[1] Amer. Journ. Sci., 1850, ser. 2, vol. ix, p. 220.
[2] V = molecular volume, i. e. molecular weight divided by the density.

The Hamlinite-Beudantite-Jarosite Group.

In a previous note in this Magazine (1900, vol. xii, p. 253) the above kind of chemical relationship was shown to subsist in the case of the crystallographically similar minerals hamlinite, florencite, plumbogummite, svanbergite, and beudantite, and it was suggested that these minerals formed a natural group. Of this group the three first minerals are phosphates, and the last two double phosphates and sulphates. The group may be made more complete by the addition of five minerals which are wholly sulphates, viz. alunite, jarosite, utahite, and the two new minerals, recently described by Hillebrand and Penfield, natrojarosite and plumbojarosite [1].

In the following table are exhibited the chemical and crystallographic relations of this group of rhombohedral minerals [2]. The molecular volumes given in the last column show an approximation to equality, so that the group behaves in this respect like the more ordinary isomorphous groups.

	Formula.	rr'.	d.	V.
Hamlinite	$AlPO_4 . SrHPO_4 . Al_2(OH)_6$	87° 2′	1·1353	142
Florencite	$AlPO_4 . CePO_4 . Al_2(OH)_6$	88 56	1·1901	143
Svanbergite [3]	$AlPO_4 . SrSO_4 . Al_2(OH)_6$	89 25	1·2063	140
Beudantite	$Fe'''PO_4 . PbSO_4 . Fe_2(OH)_6$	88 42	1·1842	155
Alunite	$AlSO_4KSO_4 . Al_2(OH)_6$	90 50	1·2520	150
Jarosite	$Fe'''SO_4KSO_4 . Fe_2(OH)_6$	90 45	1·2492	154
Natrojarosite	$Fe'''SO_4NaSO_4 . Fe_2(OH)_6$	85 54	1·1038	154
Plumbojarosite	$Fe'''SO_4Pb\frac{1}{2}SO_4 . Fe_2(OH)_6$	89 42	1·2156	154
Utahite [4]	$Fe'''OHSO_4 . Fe'''OHSO_4 . Fe_2(OH)_6$	84 9	1·0576	—

Plumbojarosite, it must be confessed, stands a little out of the picture. The isomorphism of Pb and K_2 is certainly very unusual: it is considered by Penfield to be conditioned by the controlling influence or *mass effect* of the other constituents in the complex molecule. Whether 'mass effect' is to be appealed to or not as the cause of the close crystallographic relationship of the other members of the group, it is evident that in these minerals of complex chemical composition such a grouping

[1] Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 211; and Zeits. Kryst. Min., 1902, vol. xxxvi, p. 545.

[2] Plumbogummite is left out of account owing to the lack of crystallographic data.

[3] The presence of strontia with lime in the mineral from Horrsjöberg has been determined by testing in the same way as in the case of the Westanå mineral (see previous paper, l.c., p. 252).

[4] A. Arzruni and K. Thaddéeff, Zeits. Kryst. Min., 1899, vol. xxxi, pp. 234, 244.

as $CePO_4$ can be replaced by $SrSO_4$, and $AlPO_4CePO_4$ by $AlSO_4KSO_4$, &c., without materially affecting the crystalline form. The formulae are written as above in order to make clear this chemical relationship. If doubled in order to show the isomorphism of K_2 and Pb, and written on the same plan as that adopted by Penfield, with hamlinite regarded as a pyrophosphate, they are as follows:—

Hamlinite . .	$[SrOH]_2[Al(OH)_2]_6[P_2O_7]_2$
Florencite . . .	$Ce_2[Al(OH)_2]_6[PO_4]_4$
Svanbergite . . .	$Sr_2[Al(OH)_2]_6[PO_4]_2[SO_4]_2$
Beudantite . . .	$Pb_2[Fe(OH)_2]_6[PO_4]_2[SO_4]_2$
Alunite . . .	$K_2[Al(OH)_2]_6[SO_4]_4$
Jarosite	$K_2[Fe(OH)_2]_6[SO_4]_4$
Natrojarosite . . .	$Na_2[Fe(OH)_2]_6[SO_4]_4$
Plumbojarosite . .	$Pb[Fe(OH)_2]_6[SO_4]_4$
Utahite . . .	$[Fe(OH)_2]_2[Fe(OH)_2]_6[SO_4]_4$

As further examples of similar relations connecting crystalline form, molecular volumes, and chemical composition may be mentioned the following groups of minerals.

	Formula.	System.	Elements.	V.
Monazite	$CePO_4$	Monoclinic	0·9693 : 1 : 0·9256; $\beta = 76° 20'$	47
Crocoite	$PbCrO_4$	,,	0·9603 : 1 : 0·9159; $\beta = 77° 33'$	54
Gypsum	$CaSO_4.2H_2O$	,,	0·6899 : 1 : 0·4124; $\beta = 80° 42'$	74
Brushite	$HCaPO_4.2H_2O$	,,	0·6221 : 1 : 0·3415; $\beta = 84° 45'$	78
Fergusonite	$YNbO_4$	Tetragonal (pyr. hemih.)	1 : 1·4643	47
Scheelite	$CaWO_4$	,,	1 : 1·5356	48
Chrysoberyl	$BeAlAlO_4$	Orthorhombic	0·4700 : 1 : 0·5800	36
Olivine	$MgMgSiO_4$	,,	0·4657 : 1 : 0·5865	44
Andalusite	Al_2SiO_5	,,	0·9861 : 1 : 0·7024	51
Olivenite	$Cu_2(OH)AsO_4$	,,	0·9396 : 1 : 0·6726	64
Diopside	$CaMgSi_2O_6$	Monoclinic	1·0921 : 1 : 0·5893; $\beta = 74° 10'$	66
Spodumene	$LiAlSi_2O_6$	,,	1·1238 : 1 : 0·6355; $\beta = 69° 40'$	60
Perofskite	$CaTiO_3$	Cubic	——	34
Bixbyite	$FeMnO_3$	,,	——	32
Geikielite	$MgTiO_3$	Rhombohedral	1 : 1·370 [1]	30
Ilmenite	$FeTiO_3$	,,	1 : 1·3846	32
Hematite	$FeFeO_3$	,,	1 : 1·3656	30

[1] P. von Sustschinsky, Zeits. Kryst. Min., 1902, vol. xxxvii, p. 57; abstract this vol., p. 307.

In the preceding examples the chemical relationship of the minerals in each group is made evident by taking the ordinary formulae, and the molecular volumes which show an approximate equality are calculated from these formulae.

There are cases, however, of groups of two or more minerals which are very closely related crystallographically, but have molecular volumes far from equal when these are calculated from the ordinary formulae: these formulae, moreover, show no obvious relationships. In many of these cases it is found, in accordance with the principle which seems to hold good in the case of the preceding examples, that if in each group suitable multiples of the ordinary formulae of the minerals be taken so that the molecular volumes calculated from them are approximately equal, then these new formulae exhibit a similarity in form with approximately the same number of atoms.

This principle may supply a means in some cases of determining the simplest formulae of polymeric minerals, as in the following example of rutile, brookite, and anatase.

Formulae of Rutile, Brookite, and Anatase.

In the case of *rutile*, as an aid in the determination of its simplest chemical formula, we have its close crystallographic similarity with zircon.

For these two minerals the molecular volumes are:—

$$\text{Rutile } (TiO_2), \quad V = \frac{80}{4{\cdot}2} = 19.$$

$$\text{Zircon } (ZrSiO_4), \quad V = \frac{182}{4{\cdot}7} = 39.$$

In order to bring these molecular volumes into approximate equality, that of rutile must be multiplied by 2.

The simplest formula, therefore, for rutile is Ti_2O_4 or $TiTiO_4$, which brings it into correspondence with that of zircon, $ZrSiO_4$.

In the case of *brookite*, its close crystallographic similarity with tantalite serves to suggest its formula.

The molecular volumes are:—

$$\text{Brookite } (TiO_2), \quad V = \frac{80}{4{\cdot}084^{1}} = 19{\cdot}6.$$

$$\text{Tantalite } (FeTa_2O_6), \quad V = \frac{439}{8{\cdot}200^{2}} = 62{\cdot}32.$$

[1] Penfield's determination for brookite from Magnet Cove, Arkansas. Amer. Journ. Sci., 1886, ser. 3, vol. xxxi, p. 387.

[2] Headden's determination for tantalite from S. Dakota. Amer. Journ. Sci., 1891, ser. 3, vol. xli, p. 98.

Here the molecular volume of brookite must be multiplied by 3, and the simplest formula for brookite is therefore Ti_3O_6 or $TiTi_2O_6$, to correspond with that of tantalite, $FeTa_2O_6$.

That these formulae, however, both of brookite and of tantalite, may have to be doubled is suggested by the well-known crystallographic relationship of these minerals with wolframite (hübnerite).

Thus for these three minerals the molecular volumes calculated from the simplest formulae are as follows:—

Brookite (TiO_2), $V = 19{\cdot}6$.

Tantalite ($FeTa_2O_6$), $V = 62{\cdot}32$.

Hübnerite ($MnWO_4$), $V = \frac{302{\cdot}4}{7{\cdot}177^1} = 42{\cdot}133$.

In order to bring these molecular volumes into approximate equality, the simple formulae of the three minerals must be multiplied by 6, 2, and 3 respectively, when the chemical relationship becomes at once apparent.

The molecular volumes and topic axes of the three minerals are then as follows:—

	V	χ	ψ	ω
Brookite ($Ti_3Ti_3O_{12}$),	117·54	4·450	5·288	4·994
Tantalite ($Fe_2Ta_4O_{12}$),	124·64	4·581	5·530	4·920
Hübnerite ($Mn_3W_3O_{12}$),	126·40	4·647	5·599	4·859.

In the case of *anatase* (TiO_2, $V = 20$), its close crystallographic similarity with calomel (Hg_2Cl_2, $V = 72$) and matlockite (Pb_2Cl_2O, $V = 70$) suggests that Ti_4O_8 ($V = 80$) is the most probable formula, although here the dissimilarity between the chemical compounds renders the evidence less convincing than in the case of rutile and brookite.

The most probable simplest chemical formulae therefore for the three modifications of titanic acid are:—

Rutile . . .	Ti_2O_4.
Anatase . . .	Ti_4O_8.
Brookite . . .	Ti_6O_{12}.

This result is the same as that to which Schrauf[2] was led from the consideration of atomic groupings in accordance with the crystallographic symmetry.

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[1] Hillebrand's determination for hübnerite from Ouray Co., Colorado. Amer. Journ. Sci., 1884, ser. 3, vol. xxvii, p. 357.

[2] Zeits. Kryst. Min., 1884, vol. ix, p 483.

The chemical and crystallographic relations and the molecular volumes of the above and other similar groups of minerals are exhibited in the following table:—

	Formula.	System.	Elements.	V.
Zircon	$ZrSiO_4$	Tetragonal	1 : 0·6404	39
Rutile	$TiTiO_4$	,,	1 : 0·6442	38
Sellaite	$MgMgF_4$	,,	1 : 0·6596	41
Xenotime	YPO_4	,,	1 : 0·6187	41
Brookite	$Ti_2Ti_4O_{12}$	Orthorhombic	0·8416 : 1 : 0·9444	118
Tantalite	$Fe_2Ta_4O_{12}$	,,	0·8285 : 1 : 0·8898	125
Hübnerite	$Mn_2MnW_3O_{12}$	Monoclinic	0·8300 : 1 : 0·8678 ; $\beta = 89° 22'$	126
Celestite	$SrSO_4$	Orthorhombic	0·7789 : 1 : 1·2800	47
Marcasite	$FeFeS_4$	,,	0·7662 : 1 : 1·2342	50
Copper-pyrites	$Cu_2Fe_2S_4$	Tetragonal	1 : 0·9853	88
Stannite	Cu_2FeSnS_4	,,	1 : 0·9827	95
Calcite	$Ca_2C_2O_6$	Rhombohedral	1 : 0·8543	74
Nordenskiöldine	$CaSnB_2O_6$	,,	1 : 0·8221	65
Calomel	Hg_2Cl_2	Tetragonal	1 : 1·7229	72
Matlockite	Pb_2Cl_2O	,,	1 : 1·7627	70
Anatase	Ti_4O_8	,,	1 : 1·7771	80

The principle enunciated in the present note of the approximate equality of molecular volumes corresponding to similarity in form of the chemical formulae in the case of minerals showing close crystallographic relations, although holding good for a large number of cases, is not of general application to compounds of any elements whatever. Thus the well-known homoeomorphous minerals zincite (ZnO), greenockite (CdS), and iodyrite (AgI), although having equal number of atoms in the molecule and showing the closest possible crystallographic relationship, have molecular volumes of 15, 30, and 40 respectively, which are certainly not equal, although, it may be pointed out, nearly in the simple ratio of 1 : 2 : 3. Further, the principle is not always a reversible one, for minerals having approximately equal molecular volumes and formulae similar in form may show no crystallographic similarity; e. g. neither scorodite, $FeAsO_4 . 2H_2O$ (V = 72), and gypsum, $CaSO_4 . 2H_2O$ (V = 74), nor pucherite, $BiVO_4$ (V = 53), and celestite, $SrSO_4$ (V = 47), show any close similarity in crystalline forms.

It would seem that, just as in an ordinary isomorphous group there are *single* elements which may be termed crystallographically equivalent, so in the case of the crystallographically similar minerals discussed in the

present note there are *groups* of elements which are crystallographically equivalent. Thus, as regards their influence on molecular volume and the determination of crystalline form, it would appear from the preceding examples that

CaC	is equivalent to	NaN
NaSi	,,	CaAl
CeP	,,	PbCr
YNb	,,	CaW
Al_2Si	,,	Cu_2As
$BeAl_2$	,,	$SiMg_2$, &c.

In many cases, however, especially where the chemical molecule is a very complex one, the equivalence of certain groups may be only approximate, and the fact that they can replace each other in such complex minerals without appreciably affecting the crystalline form may depend to some extent on the 'mass effect' of the other constituents of the molecule, as suggested by Penfield.

Serendibite, a new borosilicate from Ceylon.

By G. T. Prior, M.A., F.G.S., and A. K. Coomáraswámy, B.Sc., F.G.S., F.L.S.

[Read February 4, 1902.]

Mode of Occurrence.—This new mineral was discovered at Gangapitiya, near Ambakotte and about 12 miles east of Kandy, Ceylon. In this locality quarries have been dug for the well-known Ceylon moonstone, which occurs in large porphyritic crystals in an acid granulite.

Bands of this granulite, which is composed mainly of quartz and felspar in finely granulitic and occasionally graphic structure, alternate with bands of limestone up to 18 inches wide. Between limestone and granulite occur contact-zones consisting, next to the limestone, almost entirely of a colourless diopside, but near the granulite of a mixture of diopside with other minerals, viz. blue spinel, a little apatite, occasionally scapolite or plagioclase, and the blue mineral which is the subject of the present note. Hand-specimens may be collected showing this relation. The serendibite occurs in sufficiently large amount to give a deep blue colour to the contact-zones [1].

Physical Characters.—The association of the serendibite with the diopside and spinel is of such an intimate nature that no definite crystals could be isolated from the material at our disposal.

Examination of fragments of the mineral and of thin slices of the rock in which it occurs, shows that it is biaxial and probably anorthic. Besides the marked pleochroism, from very pale yellow (nearly colourless) to deep indigo-blue, the most notable feature to be observed in thin slices is the remarkable polysynthetic twinning, which is quite as intimate as that of a plagioclastic felspar.

The mineral occurs for the most part in irregular grains. In parts of the rock, however, radiating detached grains of the serendibite are seen

[1] Further details as to the mode of occurrence of the mineral will be found in Quart. Journ. Geol. Soc., 1902, vol. lviii, p. 421.

to belong to one individual crystal and to form a sort of ophitic structure with the diopside; while occasionally more definite crystals have been formed which show in thin slices traces of a prism or pinacoid, along which they are elongated and parallel to which occurs the twinning. Such crystals often show traces of two terminal faces. In the section of the crystal shown in the accompanying figure these terminal faces are inclined to each other at an angle of about 104°, and to the adjacent side planes at angles of about 138° and 122° respectively. In this crystal the extinction is nearly symmetrical and about 15° for the two sets of twin-lamellae, each of which shows the emergence of an optic axis nearly central: the pleochroism was from very pale yellow (nearly colourless) for vibrations parallel to the line of extinction to sky-blue at right-angles: compensation with the quartz-wedge took place at right-angles to the line of extinction.

Thin section of a crystal of serendibite between crossed nicols, one set of twin-lamellae being in the position of extinction. (Magnification about 12 diameters.)

As at present imperfectly determined (owing to the lack of crystals), the physical characters of serendibite are as follows:—

Biaxial, probably anorthic; polysynthetic twins with twin-plane probably a pinacoid; cleavage, none; fracture, subconchoidal; hardness, nearly that of quartz, $6\frac{3}{4}$; density, 3·42 (determined on 0·2710 gram); lustre, vitreous; colour, blue, varying in different varieties from pale sky-blue to deep indigo-blue; transparent; pleochroism, in one variety very pale yellow (almost colourless) to pale sky-blue, in another variety pale brownish-yellow to deep indigo-blue; refraction, near that of diopside, and between monobromonaphthalene and methylene iodide, about 1·7; double refraction, weak.

Chemical Composition.—The mineral is infusible: it is only slightly attacked by acids, even hydrofluoric: heated in the closed tube, it gives a little water with doubtful traces of etching from fluorine: fused with calcium fluoride and acid sulphate of potash it imparts to the flame the green colour characteristic of boron. The presence of boron was confirmed by fusing the powdered mineral with sodium carbonate, extracting the melt with water, acidifying with acetic acid and distilling with methyl alcohol; the distillate was treated with lime to fix the boracic acid and evaporated to dryness; the residue, treated with sulphuric acid, imparted a green colour to the flame of methyl alcohol, and, dissolved in hydrochloric acid, gave the characteristic red colour to turmeric paper.

Material for analysis was carefully selected as follows. Fragments of the rock were crushed and the powder retained between sieves of 30 and 60 meshes to the inch; pure grains of serendibite were then picked out with a fine brush and examined, grain by grain, under the microscope and tested for pleochroism and double refraction. Of material picked out in this way only 0·3304 gram was available for the main analysis, and 0·2406 for the alkali determination. The amount of material at our disposal did not allow of a satisfactory direct determination of the boracic acid.

The result of the analysis (G.T.P.) is as follows:—

		Molecular ratios.	
SiO_2	25·33	0·42	
Al_2O_3	34·96	0·35	
FeO	4·17	0·06	
CaO	14·56	0·26	0·69
MgO	14·91	0·37	
Na_2O, Li_2O	0·51[1]		
K_2O	0·22		
Loss on ignition	0·69		
P_2O_5	0·48		
F ?	not determined		
B_2O_3 (by diff.)	(4·17)	0·07	
	100·00		

[1] Calculated as if wholly Na_2O: the presence of lithium, however, was clearly indicated by the spectroscope.

A provisional formula is

$$10(Fe,Ca,Mg)O.5Al_2O_3.6SiO_2.B_2O_3.$$

This may be written

$$6(Fe,Ca,Mg)SiO_3.4MgAl_2O_4.2AlBO_3$$

suggestive of a combination of aluminium borate with molecules having the composition of diopside and spinel, the two minerals with which serendibite is so intimately associated. The mineral has some relationship with tourmaline in being a borosilicate of alumina, magnesia, and alkalies (including lithia). It has been formed as a contact mineral instead of tourmaline[1], probably owing to the basic conditions induced by the presence of the limestone. In many of its physical characters, colour, hardness, and density, the mineral is very similar to sapphirine.

It is hoped that more material (and especially crystals) may soon be available in order that the description of the mineral may be made more complete.

The name 'serendibite,' given to the mineral, is derived from 'Serendib,' an old Arab name for Ceylon.

[1] Tourmaline was also found very sparingly in the contact-zones, but the few crystals observed occurred only in soft material apparently filling cracks in the harder rock.

Contributions to the Petrology of British East Africa.

Comparison of volcanic rocks from the Great Rift Valley with rocks from Pantelleria, the Canary Islands, Ascension, St. Helena, Aden, and Abyssinia. (With plate V.)

By G. T. Prior, M.A., F.G.S.
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[Read March 25 and November 18, 1902.]

THE following notes on the petrology of British East Africa are the result of an examination of rock-specimens collected by Professor J. W. Gregory on his well-known expedition from Mombasa to Mt. Kenya and Lake Baringo in 1892–3, and of rock-collections from the Uganda Protectorate which have been recently presented to the British Museum by Sir Harry Johnston.

The collections include examples of the Archaean gneisses, schists, and granites which constitute the prevailing basement rocks of Central Africa; of ferruginous schists, coarse sandstones, and quartzites belonging to the Palaeozoic Karagwe series; and of an interesting series of Tertiary volcanic rocks comprising phonolites, phonolitic trachytes, riebeckite-rhyolites, kenytes, and basalts from the volcanoes of the Great Rift Valley, as well as of nephelinites and basaltic rocks containing melilite and perofskite from Mt. Elgon.

GNEISSES, SCHISTS, GRANITES, AND GRANULITES.

These are the basement rocks which occupy such a prominent position in the geology of the African continent. As is well known, the general prevalence of these rocks in Central Africa led Murchison to the hypothesis that this region, like that of southern India, is one of great antiquity which has for the most part never been below the level of the sea.

According to Prof. Gregory[1], in a journey inland from Mombasa to Uganda, after the low-lying coast region with its fringe of coral-rock and Triassic sandstone has been traversed, gneisses and schists become the prevailing rocks until the region of the Great Rift Valley is approached, when they are covered by the enormous outpourings of

[1] The Great Rift Valley. London, 1896, p. 227.

phonolitic lavas from Mt. Kenya and the volcanoes of the Rift Valley. On the western side of the valley, however, the Archaean rocks reappear in the Elgon District and Victoria Nyanza region, where they are in places covered by the ferruginous schists and sandstones of the Karagwe series: thence they extend across Uganda and constitute the main mass of Ruwenzori.

Of these rocks, specimens were collected by Prof. Gregory from the east side of the Rift Valley before the volcanic region was reached. In Sir Harry Johnston's collections from the Uganda Protectorate there are specimens of *gneiss* from the Central Province (Iganga, and the Kadudamu and Kamurujo Hills), Kavirondo (Kisumu), the Elgon District (Tindi, Marama, Ketosh, Kakumega, Nyala, Samia Hills), Unyoro, the Nile Province, and Ruwenzori; of *mica- and hornblende-schists* from the Central Province (Jinga, Nampirika, and the Nabutitisi Hills), Ankole (Egara Hills), Unyoro, Toro, and Ruwenzori; and *granites* from Toro (Katwe), Central Province (Iganga, Kakani Hill), Kavirondo (Awichina near Kisumu), and Samia Hills.

Gneisses and schists from tropical East Africa have been minutely described by Rosiwal [1], and gneisses and granulites from Massailand by Müggе [2] and by Lenk [3], so that only a few points on the microscopic examination of these rocks will be noted here.

Like many of those described by Rosiwal, the *gneisses* in the present collections are characterized for the most part by the large amount of microcline and by their granulitic structure. Some specimens of granite-gneiss from Unyoro, however, present rather the characters of crushed granites. They consist mainly of an aggregate of microcline and quartz with very little ferromagnesian mineral, and show under the microscope very pronounced cataclastic structure. A gneissic-looking rock from Diwona Camp, Ruwenzori [4], has the characters of a crushed and metamorphosed gabbro or coarse dolerite: it consists of large bent and distorted felspars showing microcline-like cross-hatchings, and large crystals of purple augite altered on the margin to hornblende and granular epidote: the interspaces between augites and felspars are occupied by a quartz-felspar-mosaic showing cataclastic structure.

In association with the gneisses and schists occur, both on the east of the Rift Valley and in Uganda, *granulites* similar to the well-known

[1] Beitr. z. geol. Kennt. d. östlichen Africa. Vienna, 1891.
[2] Neues Jahrb. Min., 1886, Beil.-Bd. iv, p. 516.
[3] Baumann, Durch Massailand zur Nilquelle. Berlin, 1894, p. 268.
[4] The specimen is from the Scott Elliot collection in the British Museum.

series in India and Ceylon to which Mr. T. H. Holland has given the name of charnockite[1]. Thus from Unyoro (Chief Matwe) comes a specimen of typical hypersthene-granulite consisting of a granulitic aggregate of quartz and oligoclase, with strings of pleochroic (colourless to rose-red) hypersthene-grains and deep brownish-red biotite in large amounts. A specimen from Kikwen, Iveti Mts., is a kyanite-quartz-granulite in which grains of deep red rutile in large amount are included in both quartz and kyanite.

At Lugard Falls, on the Sabaki River, the granulites, which occur in intimate association with the gneisses, contain, besides biotite, also much pleochroic (brownish-yellow to deep bluish-green) hornblende, and in some cases also a pale bluish-green pyroxene (sahlite). By failure of biotite and increase in the amount of hornblende, these rocks pass into *amphibolites*. In some specimens red garnet is also present, and in this case the hornblende often occurs in peculiar blebs arranged in centric structure, and the garnet contains inclusions of the quartz-felspar-groundmass and also of the green hornblende. A specimen of *granulite* from five days west of Hamaye shows under the microscope (fig. 1, pl. V) pink garnets, in large crystals with very ragged outlines and also in curious vermicular blebs, in a granular base of large plates of oligoclase showing fine twin-striations: besides the garnet, but in smaller amount, occurs the same bluish-green hornblende as in the amphibolites in patches of small blebs, in part isolated in the felspar-base but mainly completely enclosed by the garnet. Plentifully scattered through the slide and enclosed in all the other constituents are minute colourless blebs of a strongly refractive (the refraction is higher than that of the garnet) and doubly refractive mineral which is referable with little doubt to sphene, since it shows a positive biaxial figure with dispersion $\rho > v$ and an optic axial angle equal to that shown by a specimen of sphene. Peculiar centric structures of pyroxene have been recently described by Mr. A. K. Coomáraswámy in garnet-granulites from Ceylon and are attributed by him to corrosion of the garnets by a felspathic magma[2]. In the present case, however, the appearances rather suggest the idea that the garnet has grown at the expense of the hornblende, and they thus tend to favour the views of Mr. T. H. Holland[3], who considers the garnets in many of the granulites of southern India as of secondary origin and derived from pyroxenes which are undergoing amphibolization.

[1] Mem. Geol. Survey India, 1900, vol. xxviii, part 2, pp. 119–249.
[2] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 601.
[3] Records Geol. Surv. India, 1896, vol. xxix, p. 20.

A garnet-hornblende-granulite from Madagascar in the Museum collection presents characters almost identical with those of the present rock. The pink garnet and bluish-green hornblende are precisely similar, but the latter mineral occurs more plentifully in patches of small blebs in the felspar-base than enclosed in the garnets. However, some of the irregular grains of hornblende are enclosed in garnet, and in this case the contour of the latter mineral is seen to follow all the irregularities of the hornblende.

In Uganda the gneissic rocks appear to be traversed in many parts by veins both of acid pegmatites and of basic diabases (often converted into epidiorites). *Pegmatites* were found in Busoga (Iganga) and Bukedi (Kumaga and Kyabala), *diabases* at Kibui in Busoga and at Kabras in the Elgon District, and *epidiorites* on Ruwenzori, in Busoga (Iganga and Jinga), and in Unyoro.

Of crystalline *limestones* associated with the gneisses and schists, there is a specimen from the Bura Mts., Taita, which contains large crystals of a pale green diopside. Specimens in Sir Harry Johnston's collection, of earthy limestone from the Nyando Valley, Kavirondo, collected by Mr. C. W. Hobley from 'concretionary blocks in alluvial deposits overlying granite and gneiss,' are without doubt of recent origin.

FERRUGINOUS SCHISTS, SHALES, AND PHYLLITES; COARSE SANDSTONES AND QUARTZITES.

These rocks belong to the Palaeozoic Karagwe series of Scott Elliot and Gregory[1]. Rocks of this series are stated by them to occur on the Nandi Hills, where their superposition on the gneiss is clearly seen, on the Samia Hills in the Elgon District, and at Berkeley Bay on the east side of Lake Victoria Nyanza; while on the western side of that lake they extend over a distance of 100 miles from Butunguru on the Kagera River to Kiarutanga. The order of succession of the rocks belonging to this Karagwe series is given as follows:—(1) at the base, phyllites and ferruginous shales; followed by (2) red and brown sandstones; (3) coarse schistose sandstones; and (4) white granular quartzites.

In Sir Harry Johnston's collections from Uganda are many examples of these rocks. A remarkable series of ferruginous schists, shales, and phyllites comes from Unyoro (Chiefs Byabaswezi, Tibansamba, Kiza and Basigala), but there are also many specimens in the collections from Ankole, Busoga (Bukonge, Kalanga, and Jinga), and the Buvuma Islands in Lake Victoria Nyanza.

[1] Quart. Journ. Geol. Soc., 1895, vol. li, pp. 677–9.

The ferruginous schists and shales from Unyoro vary in colour from pale brown and purple to deep brick-red. Some are banded from deep-red to nearly colourless. Most of them are hard compact and siliceous rocks passing occasionally into black lydite, while others which are softer and more schistose graduate into ferruginous phyllites.

In these characters the rocks present striking similarities with Dr. F. H. Hatch's Hospital Hill series of the southern Transvaal [1], and also with rocks from the Ingwenyaberg, Swaziland, which have been described by Prof. T. Rupert Jones [2]. With specimens of both these series in the Museum collection the African rocks have been compared. The Hospital Hill series of ferruginous shales occurs in the neighbourhood of Johannesburg as part of the Cape system, with the auriferous Witwatersrand quartz-conglomerate immediately above it. The Swaziland ferruginous shales and argillites, which probably belong to the same series, occur in association with gold-bearing serpentine and talcose schists. Amongst the rocks from Unyoro are specimens of quartz presenting some points of resemblance with that of the auriferous Banket formation of the Transvaal, but no visible gold has been detected on any of the specimens from Uganda.

Altogether the similarity of these schists and shales from Unyoro with those of the Transvaal is sufficiently striking to suggest the correlation of a part at least of the Karagwe with the Hospital Hill series. In their geological position and characters these rocks are also similar to the Cuddapah series of slates and quartzites which occurs above the gneiss in southern India. The ferruginous slaty rocks through which phonolitic rocks have been erupted in the neighbourhood of Adowa and Axum, Abyssinia [3], possibly also belong to the same group.

The rocks of the Karagwe series in all probability belong to the same formations as the schists and sandstones in the neighbourhood of Lake Nyasa described by Bornhardt [4]. Thus the schistose rocks in the Kinga region to the NE. of Lake Nyasa (the Urschiefer (?) formation of Bornhardt) appear to be somewhat similar to the rocks from Unyoro, since they consist of micaceous phyllites and light violet-red and brownish-grey to black shales. That Bornhardt would include some of the Karagwe series in this formation is also clear from the fact that he states that similar

[1] Quart. Journ. Geol. Soc., 1898, vol. liv, pp. 73–99.

[2] Geol. Mag., 1899, vol. vi, p. 105; the particular rocks are marked T. B. in the sections.

[3] This Magazine, 1900, vol. xii, p. 255.

[4] Deutsch-Ost-Afrika. Band vii, Geologie, Berlin, 1900.

schists are mentioned by Reichenbach as occurring in a zone from the south and west of Victoria Nyanza along the east coast of Tanganyika up to the neighbourhood of Nyasa. To the Cape system, however, Bornhardt only doubtfully refers certain conglomerates and coarse sandstones which rest unconformably upon the Urschiefer rocks. In the present collections there are no specimens which can be said with certainty to correspond to the coal-bearing shales to the east and NW. of Lake Nyasa which are described by Bornhardt[1] and correlated by him with the Karoo of South Africa and the Gondwana system of India. Mention, however, is made in Sir Harry Johnston's description of Mt. Elgon[2] of rocks looking like sandstones and of coal-dust thickly strewn over pebbles in the stream-valleys, but no specimens are in the collection.

Of sandstones and quartzites belonging to the Karagwe series in the collections there are specimens from Bukonge on the north shore of Lake Victoria Nyanza (coarse ferruginous sandstone and white quartzite), Nakalanga in Busoga (colourless to pale purple sandstone), the Bugaya Islands, Kisubi and Tagana on the NW. borders of Lake Victoria Nyanza (ferruginous sandstones and quartzites), Ankole, and Unyoro. A white, fine-grained sandstone was also found on the east coast of Lake Naivasha at a height of 6,000 feet.

ERUPTIVE ROCKS.

The eruptive rocks connected with the Great Rift Valley cover an enormous extent of country, and are in this respect, as stated by Prof. Gregory, almost comparable with the Deccan traps of India or the Idaho basalts of North America. They were encountered by Prof. Gregory in his journey from Mombasa to Mt. Kenya soon after passing Mackakos. The immense plain extending westward at the foot of the old gneissic hills consisted of an enormous lava-flow which 'ended abruptly against the flank of the old gneiss ridge on its margin, but ran up the valleys and into the hollows of the mountains, just as the water of a lake follows the irregularities of its shore.'

This lava-region extends to the north, along the Rift Valley with its numerous craters, beyond Mt. Kenya and Lake Baringo, to the south beyond Mt. Kilimandjaro, and to the west across the Rift Valley and beyond the Mau escarpment to within a few miles of the east shore of Lake Victoria Nyanza (to Korando Hill and Kisumu).

The lavas are for the most part of a phonolitic type, rich in alkalies

[1] Loc. cit., p. 461.

[2] Geogr. Journ., 1902, vol. xix, p. 14.

and poor in lime and magnesia, but forming a rock-series varying in basicity from basic kenytes and nepheline-rich phonolites through phonolitic trachytes to acid soda-rhyolites rich in quartz. The first eruptions which gave rise to the phonolitic lavas of the Kapte Plain are stated by Gregory to have taken place in Cretaceous times; in the later eruptions of Kamasia and Laikipia, basalts are associated with the phonolitic rocks; and in the still later eruptions of Kibo (Kilimandjaro) and of the neighbouring still active volcano of Doenyo Ngai, basic kenytes and nepheline-bearing basaltic rocks appear to be the prevailing lavas.

To this later period of eruption also belong the lavas of Mt. Elgon and the Nandi District on the western side of the Rift Valley. These consist mainly of nephelinites with melilite and perofskite, somewhat similar to the 'melilite-basalts' of Doenyo Ngai described by Mügge[1], and of Makinga Hill in German South-East Africa described by Lenk[2].

Further to the west across the Central Province of the Uganda Protectorate no volcanic rocks occur until the second line of weakness marked by the line of lakes from Tanganyika to Albert Nyanza is approached. Here at the foot of Ruwenzori (which itself consists of a block of Archaean gneisses and schists cut by dykes of epidiorite) occur numerous crater-lakes with masses of volcanic tuff, and nephelinites with perofskite are again met with, suggesting that these eruptions belong to the same period as those of Mt. Elgon and Doenyo Ngai.

Further south in NW. Ankole numerous crater-lakes with tuffs occur in the neighbourhood of Lake Albert Edward Nyanza. A specimen of tuff from this district is in the collection, and a scoriaceous olivine-basalt comes from one of the volcanic mountains between that lake and Lake Kivu.

For purposes of description the eruptive rocks will be taken in the following order:—

I. The Phonolitic Series, including:—

(i) Phonolites, phonolitic trachytes, and phonolitic quartz-trachytes.

(ii) Riebeckite-rhyolites (comendites) and other soda-rhyolites.

(iii) Glassy equivalents of phonolites and soda-rhyolites.

(iv) Kenytes ('trachydolerites').

II. Basalts.

III. Nephelinites containing melilite and perofskite, borolanite, &c., from Mt. Elgon, the Nandi District, and the foot of Ruwenzori.

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 595.

[2] Lenk, Ueber Gesteine aus Deutsch-Ostafrika; in Baumann, Durch Massailand zur Nilquelle, Berlin, 1894, p. 289.

I. The Phonolitic Series.

These rocks are especially characterized by the amount and variety of soda-amphiboles (cossyrite, catophorite, arfvedsonite) as well as of soda-pyroxenes (aegirine and aegirine-augite), and (with the exception of the more ordinary type of phonolite in the Nandi District on the western side of the Rift Valley) by the absence of sphene and nosean, and also of magnetite except as inclusions in the augite-phenocrysts. The prevailing felspar is anorthoclase. They are thus closely related to the 'apachites' of Osann[1]. Almost exactly identical types, as shown later, are also presented by phonolitic rocks from the Canary Islands, the Azores, and the island of Pantelleria. Closely related trachytic rocks from Massailand, German East Africa, have been described by Mügge and by Lenk[2].

The rocks present a very striking example of a *rock-series*, showing the same gradation in character from rocks rich in nepheline at one end of the series to rocks rich in quartz at the other, as, e. g., in Brögger's grorudite-tinguaite series in the Christiania district, and in the similar series from Abyssinia described in a previous paper[3]. Mineralogically the whole group (with the exception of the more glassy rocks) is characterized by the presence of anorthoclase-felspar, and either soda-amphiboles or soda-pyroxenes or both, while in the phonolites at the basic end of the series there occurs, in addition, nepheline, and in the soda-rhyolites at the other end, quartz in large amount. Chemically the series is characterized throughout by the large amount of alkalies (especially of soda) and of iron and by the poverty in lime and magnesia. As seen in the analyses given on p. 247, the percentage of alkalies is fairly constant throughout, so that the individual rocks mainly differ in the relative amounts of the silica, alumina, and oxides of iron.

The following brief description of the more important *mineral-constituents* and their mode of occurrence applies mainly to the phonolites and phonolitic trachytes.

The *felspar*-phenocrysts are not very plentiful in these rocks. They consist mainly of clear glassy sanidines in long Carlsbad-twins showing the characteristic parting, and of anorthoclase recognizable by the minute twin-striations or mottled extinction. The larger crystals have peripheral bands of dark inclusions, and many are much corroded and partially

[1] Tschermak's Min. Mitth., 1896, vol. xv, p. 394.
[2] Loc. cit., p. 229.
[3] This Magazine, 1900, vol. xii, p. 255.

reabsorbed, in which case they often have marginal bands of aegirine-grains. The felspar-laths of the groundmass probably belong to the same species: the larger ones are in Carlsbad-twins, some giving simultaneous straight extinction in the two halves, and others showing mottled extinctions suggestive of anorthoclase.

The *nepheline*-phenocrysts are generally in sharply defined rectangular and hexagonal sections with the cleavage in some cases well marked. They often contain inclusions of augite.

Of the pyroxene group, three members are generally present, viz. a pale green diopside-like augite, aegirine-augite, and aegirine.

The pale green *augite* occurs both as small phenocrysts and as irregular grains in the groundmass. The phenocrysts usually have a margin of grass-green aegirine and often contain inclusions of large magnetite grains and also needles of apatite. They are slightly pleochroic from yellowish-green to pale green, and the extinction is as high as 43°.

The pleochroic (grass-green to yellow) *aegirine*, except as a border round the augite-phenocrysts, only occurs in needles and ragged patches in the groundmass.

The *aegirine-augite* occurs in the same way as the aegirine, from which it is distinguished by its high angle of extinction and less brilliant colour.

Of the soda-amphiboles there are many varieties present in these rocks. They occur for the most part, like the soda-pyroxenes, in ragged patches in the groundmass.

Two varieties may be referred to the *catophorite* of Brögger. One of these (α) shows pleochroism similar to that of the Lougenthal mineral, viz.

$\mathfrak{a}$ = pale brownish-yellow to colourless,
$\mathfrak{b}$ = smoky brownish rose-red,
$\mathfrak{c}$ = reddish-yellow.

Sections with traces of two cleavages inclined at an angle of about 124° showed an optic axis on the edge of the field, while prismatic sections gave extinctions up to 40°: in a prismatic section with extinction of 25° to the cleavage, compensation took place with the quartz-wedge at right-angles to the line of extinction.

The other variety (β) of catophorite showed an approach to ordinary hornblende. The pleochroism was from pale smoky brownish-yellow with a tinge of green to deep purplish-brown nearly opaque. Extinction was as high as 23° and compensation took place at right-angles to it.

The mineral referred to *cossyrite* occurs in ragged ophitic patches

and moss-like groups such as are characteristic of riebeckite. The pleochroism was $c > b > a$, with

a = smoky reddish-brown,
b = reddish-brown,
c = deep red-brown to opaque.

The extinction was as high as 43°.

In some specimens, besides the cossyrite and catophorite, occur patches of an *arfvedsonite*-like hornblende with pleochroism from pale smoky brown to pale lavender.

In the Kamasia phonolites occur also large moss-like patches of an amphibole near to *riebeckite* with pleochroism from pale brownish-yellow to a beautiful sky-blue (see fig. 4, pl. V). The riebeckite of the comendites presents the usual pleochroism and optical characters (p. 248).

Mica (*biotite*) occurs in very few specimens and then in only very small amount. It is generally partly reabsorbed and surrounded by an altered zone containing magnetite-grains and either aegirine or catophorite; occasionally it occurs as inclusions in the felspar- and nepheline-phenocrysts.

(i) *Phonolites and Phonolitic Trachytes.*

For purposes of description these rocks may be divided into five groups which graduate into each other:—

(*a*) Phonolites with nepheline in large phenocrysts.
(*b*) Phonolites with nepheline in small crystals surrounded by aegirine.
(*c*) Phonolites with nepheline in small crystals in the groundmass.
(*d*) Phonolitic trachytes with no recognizable nepheline.
(*e*) Phonolitic quartz-trachytes approaching soda-rhyolites.

(*a*) *Phonolites with Nepheline in large phenocrysts.*

In the rocks of this group phenocrysts, in small amount, of anorthoclase, sanidine, and nepheline, together with a little pale green augite, occur in a fine-grained felspar-nepheline groundmass scattered through which are ragged shreds and patches of aegirine, aegirine-augite, pale green augite, and the soda-amphiboles, dark, nearly opaque, reddish-brown cossyrite, and smoky rose-red catophorite. In this group lath-shaped felspar-microliths in the groundmass are not in large amount and flow-structure is not well marked. In the base there is generally some isotropic material (sodalite? or altered nepheline?) interspersed between the felspar-microliths, but nepheline in minute crystals is only rarely recognizable.

Four types will be described, the three first of which differ for the most part only in the mode of aggregation of the soda-amphiboles and pyroxenes, while the fourth differs from the others in containing much sphene and no soda-amphiboles.

In the first type, which may be termed the *Losuguta type*, cossyrite and catophorite are scattered in grains and small patches very uniformly through the groundmass (see fig. 2, pl. V, in which is represented a portion of the groundmass as seen under a $\frac{1}{4}$ in. objective). In most of these rocks the felspar-microliths give some idea of definite flow-structure.

Of this type are specimens from the scarp of Lake Losuguta (291–3, and 301)[1], the summit and base of Doenyo lol Mwaru (421, 424), from north of Guaso Laschau in Laikipia (433), and from south of Lari lol Morjo (429).

In a second type, intermediate between the Losuguta type and the following one, the nepheline-phenocrysts are very large and the coloured constituents occur in more tuft-like feathery forms with intervening clearer spaces. The tufts consist mainly of cossyrite and aegirine or aegirine-augite (fig. 3, pl. V), but catophorite also occurs prominently in some specimens (427), and occasionally pleochroic (pale smoky brown to lavender or sky-blue) arfvedsonite-like hornblendes take the place to a large extent of aegirine. In this type the felspar-microliths have in places a certain directional character, but there is no definite line of flow.

Specimens of this type come from Doenyo lol Mwaru (423), from south of Lari lol Morjo (430), from bottom of ravine between Gopo lol Mwaru and Alngaria (427), from north of Guaso Narok (432), and from Korando Hill and Kisumu in Kavirondo.

In the third type, which may be termed the *Kamasia type*, the tufty patches of grass-green aegirine, deep red to black cossyrite, and sky-blue riebeckite-like amphibole (p. 237) reach their highest development and present a very remarkable appearance in thin sections under the microscope (fig. 4, pl. V). These rounded patches of soda-pyroxenes and amphiboles are scattered porphyritically through the groundmass together with phenocrysts of felspar and nepheline, leaving large spaces free from coloured minerals. They occur almost like a pigment, without crystal-outlines, around groups of minute rectangular nephelines which occasionally are altered to calcite, and also about the phenocrysts of felspar

[1] The numbers in parentheses refer to the specimens in Professor Gregory's collection. Most of the localities of these specimens are given in the maps, illustrating Professor Gregory's journey, in 'The Great Rift Valley.' London, 1896.

and nepheline. In some specimens (385–6) the groundmass in which these patches occur consists mainly of felspar-microliths showing well-marked flow-structure, but in others (358) it is more crypto-crystalline and shows no flow-structure.

To this type belong specimens (385–6) from the foothills of Kamasia, and from gravel below basalt on the Kamnye River (358).

From the Nandi District on the western side of the Rift Valley comes a more ordinary type of phonolite with abundant sphene and no soda-amphiboles. A typical example is a specimen from the Sigowet Hills. This is a dark grey basaltic-looking rock showing to the naked eye large phenocrysts of nepheline with some augite and sphene. Under the microscope are seen large well-defined phenocrysts of nepheline, aegirine-augite, sphene, and a little nosean. The nephelines are generally remarkably free from inclusions, but sometimes contain a little aegirine-augite and sphene; the aegirine-augites show zonal structure with nearly colourless centres having a larger angle of extinction, and have generally a fringe of small grass-green aegirines: the sphene is in large twinned crystals, and the nosean shows inclusions of augite and sphene. The groundmass is to a large extent without action on polarized light, but contains felspar-laths and shreds of aegirine and small crystals of aegirine-augite bordered by aegirine.

Specimens from the bed of the Lower Kedowa River and the bed of the Seget River show almost precisely similar characters.

A dark grey basaltic-looking phonolite from Mt. Manava, Kavirondo, is of a more glassy type. In a glassy base, which is rendered dense with minute tufts of incipient aegirine (?), occur large nepheline-phenocrysts containing zonally arranged inclusions of augite and sphene: there are also small phenocrysts of a pale-green augite (with inclusions of magnetite), and of sphene.

(*b*) *Phonolites with Nepheline in small crystals surrounded by Aegirine* (*Kenya type*).

The type-rock of this group is the phonolite from Mt. Kenya which is figured by Professor Gregory [1]. The mineral constituents are the same as in the preceding group. The phenocrysts, however, consist mainly of felspar, and the groundmass is of coarser grain, the felspar-microliths and altered nephelines being replaced by a trachytic mesh of well-defined felspar-laths showing flow-structure. Scattered through the groundmass are small crystals of nepheline surrounded by ragged aegirine, while

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 210, pl. XI, fig. 5, and pl. XII, fig. 1.

interspersed between the felspar-laths are grains and tufts of aegirine with cossyrite and in smaller amount catophorite. The felspar-phenocrysts are mainly of anorthoclase in Carlsbad-twins showing fine twin-striations; they have generally a narrow, strongly marked band of dark dusty inclusions just within the margin.

The rocks of this group are very similar to some of the phonolites of the Canary Islands which also contain cossyrite and catophorite. They would appear also to be absolutely identical with the 'acmite-trachytes' from Massailand described by Mügge[1], were it not for the fact that they contain nepheline in place of sodalite. In many of the specimens indeed the nepheline is much altered and isotropic and thus simulates sodalite, but in others it is perfectly fresh and doubly refracting, while hexagonal sections show well-defined negative uniaxial figures.

A quantitative analysis of the type-rock from the lava-flow at the base of Mt. Höhnel on Mt. Kenya, gave the following result (I) as compared with that of a somewhat similar phonolitic rock ('tinguaite') from near Axum, Abyssinia[2] (II).

	I. Mt. Kenya.	II. Axum.
SiO_2	58·37	57·81
TiO_2	0·21	—
Al_2O_3	16·65	18·74
Fe_2O_3	4·09	5·76
FeO	3·03	0·42
MnO	0·43	—
CaO	1·66	1·28
MgO	0·37	trace.
Na_2O	7·28	9·35
K_2O	5·46	4·52
P_2O_5	0·08	—
H_2O (below 110°)	0·96	—
H_2O (above 110°)	1·40	1·50
	99·99	99·38

Specimens belonging to this group come from the Athi Plain (166), from a hill below Fort Smith, Kikuyu (158), from the NW. side of the second swamp, Kikuyu (174), from the bed of a stream south of Guaso Laschau (438), and from the east of Losuguta Scarp (281, 284).

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 590.

[2] This Magazine, 1900, vol. xii, p. 269.

(*c*) *Phonolites with Nepheline in the groundmass.*

In this group the felspar-phenocrysts are in small amount. Nepheline only occurs in the groundmass interspersed between the felspar-laths. Cossyrite and catophorite with aegirine and augite in varying relative amounts occur in ragged shreds and grains interpenetrated by the felspar-laths. The cossyrite is sometimes aggregated in minute tufts round the felspar-laths like iron-filings round a magnet. In some specimens clear isotropic patches (sodalite?) are present in small amount.

To this group belong specimens from Fort Smith in Kikuyu (160), from the plain at the foot of Doenyo Lersubugo (320), from the lava-capped plateau of Yatta to the east of Lugard's Falls (850), from the plateau above the south end of Lake Losuguta (296), from the Losuguta Scarp (275 and 285), from the Athi Plains (163), from the north end of the ridge west of Lake Kibibi (273), and from the steppes of the Kiroruma and Maranga (552).

(*d*) *Phonolitic Trachytes.*

These rocks present similar characters to those of the preceding phonolites in containing porphyritic anorthoclases and sanidines in a trachytic groundmass of felspar-laths with interstitial soda-pyroxenes and soda-amphiboles, but no recognizable nepheline is present.

Of these rocks one type is distinguished by the very strongly marked flow-structure of the felspar-laths, and by the scarcity of phenocrysts. A specimen from near Lake Baringo (311) presents a very striking appearance in section under the microscope, as it consists of a trachytic mesh of felspar-laths with a well-marked line of flow, and lenticular patches, almost continuous throughout the slide, of grass-green aegirine, nearly opaque cossyrite, and red ferrite (possibly pseudomorphous after a soda-amphibole).

Of another type nearer to that of ordinary trachytes are two specimens from Kamasia (357 from gravel below the basalt of Kamnye River, and 365 from the Mkuyuni River). They show a trachytic mesh of fairly large felspar-laths (mainly anorthoclase showing fine twin-striations) between which are interspersed irregular grains of pale-green augite, aegirine, and only a little cossyrite.

The rocks of this group are very similar to the so-called 'acmite-trachyte' of the Azores and of Kühlsbrunnen, Siebengebirge. They are also closely related to some of the more holocrystalline rocks described later (p. 247) under kenytes.

(*e*) *Phonolitic Quartz-Trachytes.*

These rocks show fairly large phenocrysts of felspar (mainly anorthoclase in Carlsbad-twins) and, very sparingly, small green augites, in a mesh of felspar-laths micropoecilitic in a paste of quartz which depolarizes in patches. Uniformly distributed through the slide in large amount are ragged shreds of aegirine-augite, a little cossyrite, and much catophorite of the second variety (β). Characteristic of these rocks is the mode of occurrence of the quartz, not in phenocrysts but in micropoecilitic patches, forming a paste for the felspar-laths.

Precisely similar characters are presented by rocks from Punta Pozzolana, Pantelleria.

In this group are included specimens from Kikuyu Scarp (184, 194, 195), Kedong Scarp (182), Longonot (223), Equator Ridge (267), and Kirianduri (257).

(ii) *Riebeckite-Rhyolites* (*Comendites*) *and other Soda-Rhyolites.*

From Gilgil, north of Lake Naivasha, come some remarkable rocks characterized by their large contents of riebeckite and quartz. They appear to represent the volcanic equivalents of hypabyssal paisanites, and to form the most acid differentiation product of the soda-rich magma which has given birth to the flows of phonolitic lavas of the Rift Valley. In these rocks the pyroxenic minerals, green augite and aegirine, so characteristic of the phonolitic rocks, have been almost wholly replaced by the soda-amphibole, riebeckite. Examples of these rocks from Lake Naivasha have already been described by Mügge [1] and are included by Rosenbusch in the group of soda-rhyolites called 'comendites.'

The specimens in the collection made by Professor Gregory show some diversities in structure. A specimen (234) from south of Gilgil exhibits a pronounced flow-structure well marked by dense narrow bands, consisting mainly of riebeckite, alternating with clearer bands in which riebeckite has separated in small tufts and ragged needles, some of which project into cavities. The base consists of a micropoecilitic intergrowth of quartz and felspar, the clear quartz depolarizing in patches and forming a sort of paste in which are distributed clusters of felspar-microliths showing flow-structure. In this respect the base is thus somewhat similar to that of the phonolitic quartz-trachytes just described. The

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 596.

riebeckite-needles show pleochroism from pale yellow for vibrations across their length (c-axis of indicatrix) to deep indigo-blue and almost opaque along the length (a): the extinction is nearly straight and compensation with the quartz-wedge takes place along the length. No porphyritic constituents are present and no definite glass can be seen.

A specimen from the centre of the lava-flow of Doenyo Buru, south of Gilgil, shows a similar quartz-felspar base, but here the riebeckite, instead of forming bands marking flow-structure, is very uniformly distributed in small ragged tufts and moss-like patches, and also in more definite crystalline grains in clearer quartz patches. From such grains, some of which showed the hornblende cleavage of about 124°, the pleochroism could be determined as

$\mathfrak{a}$ = deep indigo-blue,
$\mathfrak{b}$ = deep blue to opaque,
$\mathfrak{c}$ = pale smoky yellow.

Besides the riebeckite, a little cossyrite was also present.

A rock (239) from a lava-flow below pumice, south of Gilgil, has somewhat different characters. It shows a similar quartz-felspar base, but no definite riebeckite occurs in the section, its place being taken, in small amount only, by aegirine and acmite (?) needles. The mineral here doubtfully referred to acmite occurs in small needles and radiating groups and also as an outer zone round aegirine-grains: it is strongly doubly refractive, compensates with the quartz-wedge along the length, and shows pleochroism:—$\mathfrak{a}$, along the length, reddish-orange; $\mathfrak{c}$, across the length, pale yellow.

A specimen (233) from a flow south of Gilgil is of coarser grain and porphyritic. It shows rounded and corroded phenocrysts of anorthoclase with some rounded crystals of pale green augite and rose-red catophorite, in a felspathic base containing some quartz.

The catophorite showed a hornblende cleavage of about 124° and had pleochroism:—

$\mathfrak{a}$ = pinkish-yellow,
$\mathfrak{b}$ = rose-red,
$\mathfrak{c}$ = pale pinkish-brown.

The extinction was as high as 36° and compensation with the quartz-wedge took place at right-angles to it.

To this group of rocks may also be referred a specimen (225) from Kigate Crags, east of Longonot. It is, however, in parts much more coarse-grained and approaches in structure the paisanite from Mt. Scho-

loda, Abyssinia, described and figured in a previous paper[1]. Large phenocrysts of clear Carlsbad-twins of sanidine and rounded quartz occur in large amount in a base varying in texture in different parts of the slide, but similar to that of the preceding rocks in consisting of a quartz-paste depolarizing in patches in which are distributed small prismatic felspars. Scattered uniformly through the slide in large amount are irregular grains and patches of riebeckite. A few phenocrysts of an altered brown hornblende with extinction (c-axis of indicatrix) of about 10° also occur and are generally surrounded by a border of projecting grains of riebeckite. Most of the felspar-phenocrysts are bordered by a zone of alteration marked by radiating felspar-laths and ferrite with riebeckite.

(iii) *Glassy equivalents of Phonolites and Soda-Rhyolites.*

The vitreous lavas vary considerably in chemical composition, for whereas some are the glassy equivalents of the phonolites and phonolitic trachytes, others are of a more acid type and have the composition of the soda-rhyolites or pantellerites.

Of phonolitic obsidians there are specimens from the rim of the crater of Longonot (222), the north face of Doenyo Nyuki (203), Losuguta Scarp (298), lake-terrace of Lake Suess (211), and Lake Nakuru. All of these show well-marked flow-structure.

The rock from Losuguta Scarp consists of a glassy base crowded with rounded dirty green patches of incipient aegirine, with here and there more definite aegirine-needles, and scattered felspar-microliths. It has characters somewhat similar to those of the rock from Lewis Col, Mt. Kenya, described by Professor Gregory[2], and also to those of rocks from Pantelleria.

Of more glassy character are the rocks from Longonot and Doenyo Nyuki. These are made up mainly of small deep brown spherulites showing well-marked black crosses between crossed nicols: a few needles of aegirine and one or two porphyritic anorthoclases are present. Phonolitic obsidians (so-called 'rhyolites') in the British Museum collection from the Vallée de Ucanca, Teneriffe, have very similar characters.

The rock from Lake Suess consists partly of spherulitic and partly of red palagonite-looking material. It contains large sanidine-phenocrysts remarkable for their clearness and freedom from inclusions. A few small

[1] This Magazine, 1900, vol. xii, p. 263, fig. 3, pl. 3.
[2] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 212.

crystals of a hornblende near to catophorite are also present: these show pleochroism:—

$\mathfrak{a}$ = pale yellow with a tinge of red,
$\mathfrak{b}$ = smoky rose-red,
$\mathfrak{c}$ = greenish-yellow,

as determined in prismatic sections and in one showing a well-marked hornblende cleavage inclined at an angle of about 124°.

The rock from Lake Nakuru is a glassy black scoria consisting of a streaky intermixture of a nearly colourless glass with a deep brown almost opaque glass. Small phenocrysts of olivine, aegirine, and anorthoclase occur very sparingly. The colourless glass is crowded with skeleton-crystals of very pale green augite, and brown needles, together with minute oval patches differentiated from the clear glass by being less transparent and of a brownish tinge: in many cases these patches are seen to be halos round needle-shaped microliths and skeleton-crystals of felspar.

A chemical analysis of this rock gave the following result:—

SiO_2	...	...	64·00
TiO_2	...	...	0·78
Al_2O_3	...	...	10·43
Fe_2O_3	...	...	6·30
FeO	...	...	3·86
MnO	...	...	0·37
CaO	...	...	1·45
MgO	...	...	0·34
Na_2O	...	...	7·59
K_2O	...	...	4·59
H_2O	...	...	0·17
			99·88

Of clear, compact, colourless (in thin section) obsidians there are specimens from Equator Peak (277) and from Lake Naivasha. These consist almost wholly of glass containing very minute felspar-microliths (visible between crossed nicols) and a few minute needles of aegirine.

An analysis of the rock from Lake Naivasha gave the following result (I), which shows the close relation of the rock to the pantellerites; the analysis[1] of a specimen of which from Cuddia Mida, Pantelleria, is given under II:—

[1] Rosenbusch, Elemente d. Gesteinslehre, 1898, p. 257.

	I.* Lake Naivasha.	II. Pantelleria.
SiO_2	70·61	69·02
TiO_2	0·15	—
Al_2O_3	8·59	10·09
Fe_2O_3	2·52	4·42
FeO	5·96	4·56
MnO	0·34	—
CaO	0·61	1·45
MgO	0·07	0·76
Na_2O	6·77	6·29
K_2O	4·46	3·70
H_2O	0·10	—
	100·18	100·29

(iv) *Kenytes* (' *Trachydolerites* ').

From the Rift Valley come, besides the phonolites and trachytes, also rocks similar to those which occur so extensively on Mt. Kenya, both as lava-flows and as part of the core, and to which Professor Gregory has given the name kenyte.

As previously pointed out by me[1] and also recently by Dr. L. Finckh[2], precisely similar rocks occur on Kilimandjaro. They have been referred by Dr. Finckh to Rosenbusch's somewhat unsatisfactorily named group of ' trachydolerites.' The rocks agree so far with Rosenbusch's definition of this group in having characters in some respects intermediate between phonolites and tephrites. They would form, however, a distinct type (kenyte-type) of the group, especially characterized by the presence of anorthoclase as the prevailing felspar. I am inclined to regard them as members at the basic end of a phonolitic rock-series of which the pantellerites and comendites are the acid equivalents. Chemically at least, although not altogether mineralogically, they stand in fact at the basic end of the phonolitic series just described (p. 235). Some kenytes from Kilimandjaro (e. g. the so-called ' nepheline-basanite ' of Hyland) and from the Canary Islands (p. 256) are so far like phonolites that they contain nepheline and leucite. The results of chemical analyses which I have made of two specimens of kenyte from Mt. Kenya are given in the

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 221.

[2] Ueber die Gesteine des Kenya und des Kilimandjaro. Centralblatt Min., 1902, pp. 204–5.

following table, in which are shown the chemical relationships of four members (basic, intermediate, and acid) of the phonolitic rock-series, viz.

I. Kenyte from the core of Mt. Kenya (Teleki Valley).
II. Kenyte from the lava-flow at the foot of Mt. Höhnel, Mt. Kenya.
III. Phonolite from the base of Mt. Höhnel, Mt. Kenya.
IV. Phonolitic obsidian from Lake Nakuru.
V. Obsidian (glassy soda-rhyolite) from Lake Naivasha.

	I. Kenyte.	II. Kenyte.	III. Phonolite.	IV. Phonolitic obsidian.	V. Soda-rhyolite.
SiO_2 . . .	53·98	53·80	58·37	64·00	70·61
TiO_2 . . .	0·57	0·31	0·21	0·78	0·15
Al_2O_3 . . .	19·43	18·46	16·65	10·43	8·59
Fe_2O_3 . . .	4·39	6·22	4·09	6·30	2·52
FeO . . .	2·05	0·40	3·03	3·86	5·96
MnO . . .	0·26	0·33	0·43	0·37	0·34
CaO . . .	2·04	2·53	1·66	1·45	0·61
MgO . . .	1·07	1·05	0·37	0·34	0·07
Na_2O . . .	8·81	7·09	7·28	7·59	6·77
K_2O . . .	5·27	5·46	5·46	4·59	4·46
P_2O_5 . . .	0·30	0·53	0·08	—	—
H_2O below 110°	0·13	0·85	0·96	—	—
H_2O above 110°	1·66	3·54	1·40	0·17	0·10
	99·96	100·57	99·99	99·88	100·18

Of the specimens of kenyte from the Rift Valley, rock (408) from Domo Larabwal appears to be a typical example precisely similar to the rock from the core of Mt. Kenya. The large porphyritic anorthoclases with inclusions of the base, and the very pale-green augite and altered olivine, are identical in character. These phenocrysts occur in a dense brown, apparently glassy base, in which a few felspar-microliths can be distinguished.

Other specimens are of a less glassy type, and show an approach to the phonolitic trachytes. These show phenocrysts of anorthoclase (generally not so plentiful nor so large as in the typical kenytes), a few small pale-green augites, and, still more sparingly, olivine in a more or less glassy base of felspar-laths with interstitial opacite (possibly altered soda-amphiboles) and a little augite. Specimens from the descent to Lake Elmenteita (248), crags behind Naivasha Camp (250), east of Mivironi

(265), first swamp, Kikuyu (170), second swamp, Kikuyu (175) have a fine-grained base of felspar-microliths with intermixed streaky patches of more glassy material; but specimens from the ridge just west of Kedong Col, and from the ridge on the floor of the first fault valley in West Kikuyu, are of coarser grain and contain no glass.

II. Basalts.

To judge from the present collections, basalts play in the Rift Valley eruptions a very minor rôle compared with that of the phonolitic lavas.

In Professor Gregory's collection there are specimens from Kamasia and Laikipia, the Tana Steppes, south of Guaso Nyiro, and Kibwezi. In Sir Harry Johnston's collections, besides the basalt-scoria from Ankole, the only specimens of Tertiary felspar-basalts are from Kamasia. Specimens, however, of what are probably much more ancient basalts occur in association with the gneiss at Bedden in the Nile Province and at Ketosh in the Elgon District: an intrusive basalt also occurs in the ferruginous shales of Unyoro.

Of the Laikipia basalts, those of Domo Larabwal are remarkable for the number and large size of the phenocrysts of olivine and purple augite. They are mainly magma-basalts near to limburgite, and consist of a very dense glassy base, containing much magnetite, some purple augite, and only a little felspar, in which are distributed numerous and large phenocrysts of clear olivines and pale-brown to purple zonal augites. The basalts from south of Rangatan Nado (443, 447) are of a different and more ordinary type and consist of a fine-grained mesh of felspar-laths, magnetite, and much purple augite, with only a few small phenocrysts of olivine and augite.

A specimen from Malungu, Tana Steppes (555), is similar to the basalts of Domo Larabwal in containing large phenocrysts of olivine and augite (sometimes intergrown), but is much more felspathic, as it contains phenocrysts of long prismatic plagioclase-felspars, and also felspar-laths in the base together with the augite and magnetite: the latter is in rods, often arranged at right-angles to the principal axis of the olivine.

The ropy basalt-lava of Kibwezi (851) consists of a dense, nearly opaque, glassy base, in which are distributed olivine-phenocrysts in large amount with some shar ly-defined felspar-laths and only a little augite: on the surface, the rock consists of a clear yellow glass containing the same phenocrysts.

Of the specimens from Kamasia some are ordinary felspar-basalts consisting of phenocrysts of plagioclase, yellow augite, and much altered olivine in a base of felspar-laths, augite, and magnetite, but others show characters in some respects intermediate between the phonolitic rocks and basalts, and may thus be referred perhaps to Rosenbusch's 'trachy-dolerites.'

A specimen of this kind from the slope of the basalt-plateau of Kamasia (389) consists of a trachytic mesh of felspar-laths, mostly in Carlsbad-twins with low angles of extinction, interspersed between which are distributed irregular grains of purple augite and some magnetite. With the purple augite is also a little green aegirine and catophorite, and some of the purple augites have green edges.

III. Nephelinites, etc., from Mt. Elgon, the Nandi District, and the Foot of Ruwenzori.

These basic rocks, and also probably the phonolites containing sphene described on p. 239, belong to a later period of eruption than the cossyrite- and catophorite-bearing phonolitic rocks of the Rift Valley. They represent therefore, in all probability, the later differentiation products of the soda-rich magma which gave birth to these earlier phonolitic lavas. Besides differing from the latter in greater basicity and larger contents of lime and magnesia, they appear to be further differentiated from them by the greater amount of titanic acid, which in the more basic rocks is present in the mineral *perofskite*, and in the more acid in *sphene*.

The nephelinites consist mainly of yellow augite, nepheline, and some magnetite, but in some cases the nepheline is partially, and in others almost wholly, replaced by melilite. In the latter case the rocks, to be consistent in rock-nomenclature, may be referred to as *melilitites*, although the name is somewhat cacophonous.

At a height of 8000 feet on Mt. Elgon occurs a *tuff* containing fragments not only of altered nephelinite, but also of the borolanite-like rock and of the jacupirangite-like rock described below.

Nephelinites and melilite-nephelinites.

These are dark basaltic-looking rocks generally showing numerous fairly large phenocrysts of augite.

A specimen from Mt. Elgon (8000 feet) shows under the microscope numerous phenocrysts of yellow augite and a few rectangular sections

of an altered mineral (probably melilite) in a dense base consisting of nepheline in square and hexagonal sections with interstitial augite-needles and grains of magnetite. Large grains of magnetite are scattered through the slide, some included in the augite-phenocrysts. These augites are very irregular in outline, are not pleochroic, show well-marked nearly rectangular cleavage, and give extinctions as high as 42°.

Two specimens from a lower elevation on Mt. Elgon (7000 feet) present very similar characters, but approach to augitites, since the nepheline in the base is much less prominent, and in one appears to be wholly replaced by glass: in the latter rock, besides the augite-phenocrysts, there are also a few altered olivines, and some of the augite-needles of the base where they project into cavities filled with analcite (?) have terminations of grass-green aegirine. In neither of these rocks are there any phenocrysts of altered melilite or nepheline.

From the Sigowet Hills and Seget Valley, Nandi, come nephelinites of a less basic character, in which the phenocrysts consist mainly of fairly large nephelines and very little augite: rectangular phenocrysts of altered melilite (?) are also present. The base is similar to that of the nephelinite of Mt. Elgon (8000 feet), and contains much magnetite, but the nepheline, in fairly large rectangular and hexagonal sections, is in greater amount. Scattered through the slide are fairly large grains of purple perofskite.

Similar in many respects to the nephelinites of Mt. Elgon are two rocks from the Nandi District, one from the bed of the upper waters of the Lower Kedowa River, and the other from the Nyando River. They contain precisely similar phenocrysts of yellow augite; but nepheline, both as phenocrysts and in the base, is in the first partially, and in the second almost wholly, replaced by melilite. The augite-phenocrysts are large, but not so numerous as in the Mt. Elgon rocks: in the Nyando rock most of them are surrounded by a fringe of melilite-needles.

The *melilite*-phenocrysts are fairly large and have a slight brown tinge; some show rectangular sections with straight extinction, but most are rounded and partially reabsorbed: the refraction is fairly high, but the double refraction low, and they depolarize in bluish-grey tints. Prismatic sections of the phenocrysts and the needles of the groundmass compensate with the quartz-wedge across the length like the Hochbohl melilite, and one of the phenocrysts, which remained dark between crossed nicols, showed a good negative uniaxial figure. The dense groundmass of these rocks consists of melilite-needles, some rectangular sections of nepheline, much yellow augite in needles, much magnetite,

and some glass. Perofskite, the common associate of melilite, is present, but not in large amount, in grains sometimes enclosed in augite and also in the larger grains of magnetite.

In order to isolate the melilite in the Nyando rock for further examination, a mineral separation by means of methylene iodide was made on powdered material which had been passed through a sieve of 100 meshes to the inch. By continued dilution of the methylene iodide with benzol the material was separated into the following portions :—

(1) Sank in methylene iodide.

Under the microscope this portion was seen to consist mainly of magnetite (separable by a magnet) and yellow augite : perofskite was also seen.

(2) Sank with spodumene.

Mainly augite with some magnetite.

(3) Sank with tourmaline.

Augite and magnetite with attached fragments of the base, and grains of melilite in large amount. Many of these melilite grains showed a well-defined central negative uniaxial figure; they gelatinized with hydrochloric acid, and showed the presence of silica, alumina, and lime.

(4) Sank with calcite.

Mainly aggregates of magnetite, augite, and base, with a little melilite, some grains showing good uniaxial figures.

(5) The residue consisted mainly of aggregates of augite, magnetite, and base, with a few colourless grains, probably of nepheline, and alteration products.

In connexion with these rocks from Mt. Elgon, it is of interest to note the occurrence in the volcanic region at the foot of Ruwenzori of a perofskite-bearing nephelinite, suggesting the idea that the eruptions in this region on the western side of Lake Victoria Nyanza belong to the same period as those of Mt. Elgon. A specimen of this rock from between Katwe and Chukaronga in the Scott Elliot collection is a fine-grained basaltic-looking rock showing no phenocrysts. Under the microscope it is seen to consist of a fine-grained aggregate of small prismatic pale greenish-yellow augites, magnetite-grains, and numerous small crystals of purple perofskite uniformly distributed in a paste of nepheline and a little isotropic material. The perofskite has precisely the same colour as the mineral from Mt. Elgon : many of the crystals

are apparently interpenetration twins formed of four lozenge-shaped individuals fitted together in the form of a cross with the axes at right-angles. Other sections of twin-crystals show only three individuals with axes inclined at 120°. These appearances are much in favour of the view that the cubic character of perofskite is due to mimetic twinning, and that the optical anomalies are therefore not due to secondary causes as advocated by Klein and Ben Saude.

A mineral separation of this rock in order to isolate the nepheline was made in the same way as in the case of the preceding melilite-rock. The following particulars are given to indicate the degree of separation which can be effected by means of heavy liquids in the case of a very fine-grained rock. By continued dilution of the methylene iodide a portion of the rock which was ground down so as to pass through a sieve of 120 meshes to the inch was divided into the following parts :—

(1) Sank in methylene iodide, tourmaline floating.
Magnetite, augite, and perofskite : grains of the latter decomposed by sulphuric acid gave a strong titanic acid coloration with hydrogen peroxide.

(2) Sank with tourmaline, calcite floating.
Mainly augite ; a little magnetite.

(3) Further diluted, calcite still floating.
Mainly augite, fine-grained.

(4) Further diluted, but calcite still floating.
Aggregates of augite and nepheline with a little attached magnetite and perofskite : coarse-grained.

(5) Sank with calcite, quartz floating.
Similar aggregates to (4), but a larger proportion of nepheline and little or no magnetite.

(6) Sank with quartz, moonstone floating.
Grains consisting mainly of nepheline and probably a little felspar, but still with a little augite attached.

(7) Sank with moonstone, leucite floating.
Mainly nepheline with a few grains giving oblique extinction (felspar): some grains still with augite attached. A portion of the nepheline was tested chemically : it gelatinized with hydrochloric acid, and showed the presence of silica, much alumina, and soda, with only a little lime.

(8) Sank with leucite.

Brown alteration products and a little nepheline.

(9) A slight residue left floating consisted of similar alteration products.

Phonolite with Melanite, allied to Borolanite.

This rock occurs in fragments in a tuff from Mt. Elgon (8000 feet). Under the microscope (fig. 5, pl. V) are seen phenocrysts of nepheline, sharply defined small aegirine-augites, and large zonal melanites in an altered groundmass probably originally consisting of nepheline and felspar with some cossyrite. The nepheline-phenocrysts are large and plentiful, and give sharply defined rectangular and hexagonal sections: one section shows inclusions of perofskite. The aegirine-augites are pleochroic, from pale yellow to green, and have a border or terminations of grass-green aegirine. The melanites contain inclusions of aegirine-augite and sphene.

Augite-Perofskite-Magnetite rock allied to Jacupirangite.

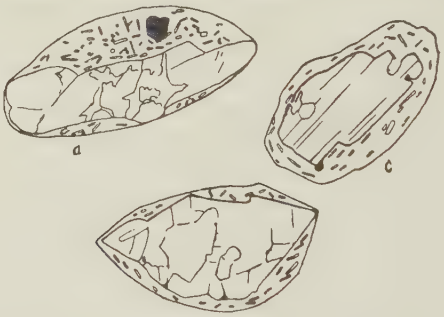
In the same tuff from Mt. Elgon (8000 feet) were dark patches consisting of a coarse-grained aggregate (fig. 6, pl. V) of yellowish brown augites (precisely similar to the augite of the nephelinites), purple perofskites, and magnetite, with some interstitial apatite and a little biotite. The perofskite is doubly refractive, and shows between crossed nicols striae parallel to the cube-faces. This rock suggests analogies with the jacupirangite of Brazil, and with some of the basic differentiation products of the nepheline-syenite of the island of Alnö, Sweden.

Tuff from the foot of Ruwenzori.

The specimen of this tuff in the Scott Elliot collection (No. 96) has been already referred to by me in a paper by Mr. M. Fergusson on the geology of Tanganyika northwards[1]. It is from one of the small volcanic cones which with small crater-lakes are found so extensively on the plain round Ruwenzori. It is of interest from the character of the lapilli which, with fragments of biotite, felspar, and magnetite, constitute the bulk of the rock. These lapilli vary considerably in size, but almost all of the larger ones consist mainly of fragments of gneissic rocks and amphibolites or of mineral fragments (chiefly biotite) from them, enclosed in only a thin film of volcanic material. These fragments have obviously been torn from the walls of the vent during the eruption, and after having been coated with the molten lava have then been ejected as lapilli. In

[1] Geol. Mag., 1901, vol. viii, p. 368.

the adjoining figure three of these lapilli (*a*, *b*, *c*) are represented as seen under the microscope under a magnification of about 16 diameters. In *a* and *b*, fragments consisting of aggregates of felspar and quartz, and in *c*, a piece of biotite, are seen surrounded by a film of glassy volcanic



Lapilli in tuff at the foot of Ruwenzori. They consist of fragments of ancient rocks torn from the walls of the vent and enclosed in a film of lava.

rock containing felspar-needles [1], magnetite, and a little yellow augite. In many of the lapilli the felspar of the enclosed fragment is seen to consist mainly of microcline. One fragment enclosed in lava is an amphibolite, consisting mainly of a pleochroic (yellow to green) hornblende, and pale green diopside with some quartz and felspar.

Comparison of Phonolitic Rocks of British East Africa with those of Pantelleria, the Canary Islands, St. Helena, Ascension, Aden, and Abyssinia.

In the preceding pages attention has been called several times to similarities between phonolitic rocks of the Great Rift Valley and those of Pantelleria and the Canary Islands. In the present section this similarity will be further emphasized by a brief description of particular specimens from these localities, and at the same time somewhat similar rocks from St. Helena, Ascension, and Aden will be discussed.

Pantelleria.

Rosenbusch [2] has described the occurrence in phonolitic trachytes from Pantelleria of the same pleochroic (brown to violet) mineral (catophorite) as was found by Mügge in the 'acmite-trachyte' from the Azores.

A specimen of phonolitic trachyte from Montagna Grande in the British Museum collection shows large phenocrysts of anorthoclase, a

[1] Many of the needles consist of calcite, and possibly represent altered melilite.

[2] Mikr. Phys. Ges., 3rd ed., 1896, vol. ii, p. 812.

few green aegirine-augites, and some olivine (with inclusions of magnetite) in a fine-grained trachytic mesh of felspar-laths with interstitial catophorite, augite, and a little cossyrite. This rock is very similar to the rocks from the Rift Valley, having characters intermediate between kenytes and phonolitic trachytes, described on p. 247.

To the more acid type of phonolitic trachyte belongs a specimen from Punta Pozzolana, in which phenocrysts of anorthoclase occur in a base of felspar-laths and micropoecilitic patches of quartz with interstitial thickly distributed cossyrite, catophorite, and augite. The rock is thus almost precisely similar to the phonolitic quartz-trachytes described on p. 242.

A phonolitic obsidian from Montagna Grande, consisting of a brown glass with small, nearly opaque, spherulitic patches and a few small phenocrysts of rounded deep reddish-brown cossyrite, grass-green aegirine and anorthoclases, resembles (except for the presence of the cossyrite) the spherulitic rocks described on p. 244.

As already pointed out, the glassy pantellerites are in chemical composition very similar to the glassy soda-rhyolites of the Rift Valley.

In Pantelleria, therefore, there appears to be a series of alkali-rich rocks analogous to the series found in the Rift Valley. The range, however, appears to be more limited, with silica percentages varying from about 60 to 74, according to the analyses of Förstner[1], and no rock strictly analogous to the typical glassy kenyte from Mt. Kenya has been found in the British Museum collection from Pantelleria. Its place, however, may possibly be taken by a rock from Punta Pozzolana, which has characters intermediate between those of a basalt and trachyte, and may thus be referred to Rosenbusch's 'trachydolerites.' In this rock very large phenocrysts of anorthoclase, with some small purple augites and a little olivine, occur in a medium-grained ground-mass of felspar-laths (mainly plagioclase), purple augite, and magnetite in skeletal crystals.

Canary Islands.

The occurrence of catophorite and cossyrite accompanying aegirine in phonolitic rocks from Gran Canaria and Teneriffe has already been pointed out in a previous paper[2]. Some of the phonolites are precisely similar to the phonolite from Mt. Kenya with nepheline surrounded by aegirine, and the phonolitic trachytes are similar to those described on p. 241. In some of these, however, the ordinary catophorite is replaced by ragged patches of a soda-amphibole presenting somewhat different pleochroism,

[1] Förstner, Nota preliminare sulla geologia dell' Isola Pantelleria. Boll. Com. Geol. d'Italia, 1881, vol. xii, pp. 523–56.

[2] This Magazine, 1901, vol. xiii, p. 89.

from pale grey with a tinge of green for vibrations along the line of extinction ($a : c = 30°$) in prismatic sections, to pale smoky brown with a tinge of purple at right-angles.

The coarse-grained *theralite*, fragments of which have been ejected as bombs in Gran Canaria, presents some points of resemblance with the crystalline rock from the core of Mt. Kenya[1]. It consists of a coarse-grained aggregate of long prismatic plagioclastic felspars and plates of nepheline, with large pleochroic (pale yellow to pinkish-purple) augites surrounded by a zonal intergrowth of pleochroic (light brown to deep reddish-brown) basaltic hornblende similar to that in the rock from Mt. Kenya: the same hornblende is further plentifully distributed in small prismatic crystals together with sphene and apatite in patches grouped round the augites.

In this connexion may be mentioned a coarse crystalline rock (probably a bomb) from Pena, Fuerteventura, having the characters of an *essexite*. It consists of a coarse-grained aggregate of labradorites (symmetrical extinction of 32°) with large ophitic plates of the same basaltic hornblende as in the preceding rock, together with some biotite, pale purple augite (often enclosed in the hornblende), sphene, and apatite.

Glassy phonolitic rocks from Teneriffe (Vallée de Ucanca), with brown spherulites, and porphyritic anorthoclases and small pale-green augites, are very similar to some of the glassy rocks from the Rift Valley described on p. 244.

The striking resemblance of the rocks from the Canary Islands with those of the Rift Valley is further emphasized by the occurrence from the Caldera of Gran Canaria of a typical *leucite-kenyte*, very similar, both macroscopically and microscopically, to the kenyte of Mt. Kenya. The rock is of a deep-brown colour, and shows numerous fairly large phenocrysts of anorthoclase. Under the microscope, phenocrysts of a pale purple augite and large anorthoclases showing minute twin-striations are seen in a glassy base (dense with brown dusty inclusions), through which are scattered a few felspar-laths and fairly numerous bright hexagonal and octagonal sections of leucite showing characteristic zonal bands of dark inclusions.

St. Helena.

In this island, with the basalts are associated phonolitic rocks bearing some relation to the rocks of the Rift Valley. Thus a specimen in the British Museum collection[2] from the rock-mass known as Lot's Wife is

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 208.

[2] The specimens here described belong to a collection presented by Mr. R. L. Antrobus in 1891.

a phonolite somewhat like the rock from Mt. Kenya, showing minute nephelines surrounded by aegirine, which also occurs in feathery patches together with the same pale greyish-brown amphibole as in the phonolitic trachyte of Gran Canaria described above.

Other specimens of phonolitic rocks from the prominent peak Lot are of a somewhat different type, and present many points of similarity, both macroscopic and microscopic, with the rocks from near Axum, Abyssinia, described (and figured) as allied to sölvsbergite in a previous paper[1]. Like the Abyssinian rocks they show a peculiar surface shimmer, due to the platy arrangement of the felspars, and the most prominent constituents are grass-green aegirine in shreds and small grains interspersed between lath-shaped felspars (probably anorthoclase) giving curious undulose extinctions and showing very conspicuous wavy lines of parting (see fig. 4, pl. 3, l. c.); but in the St. Helena rocks, in addition to these constituents, there are present small nephelines and a little cossyrite. The rocks are medium-grained, the felspar-laths being fairly large; in some cases there is an approach to porphyritic structure by larger felspars occurring in a base of smaller laths.

The occurrence in St. Helena of these isolated peaks of phonolite projecting through the overlying basaltic lavas reminds one of the similar association of phonolites and basalts on Fernando Noronha and the Little Island of Trinidad, South Atlantic[2].

Ascension.

In this island the augite-trachytes and obsidians described by Renard[3] appear to play the same rôle in association with the basaltic lavas as the phonolites with the basalts in St. Helena.

Examination of specimens in the British Museum collection shows that most of these trachytes are of a distinctly soda-rich phonolitic type, and that they contain anorthoclase-felspar and the soda-amphiboles, riebeckite and cossyrite. As pointed out by Renard, quartz is present in these trachytic rocks, but there would appear to be no good reason for regarding it in all cases as of secondary origin. In most of the specimens it occurs, in fact, in the base, depolarizing in patches and enclosing felspar-laths, and thus forming a micropoecilitic structure of precisely the same character as that in the phonolitic quartz-trachytes and in the riebeckite-rhyolites of the Rift Valley described on p. 242.

The *riebeckite* occurs in these rocks in characteristic moss-like patches

[1] This Magazine, 1900, vol. xii, p. 265, and fig. 4, pl. 3.

[2] This Magazine, 1900, vol. xii, pp. 317–23.

[3] Challenger Reports, Physics and Chemistry, vol. ii, pt. 4, pp. 39–74.

scattered through the base: it shows the usual pleochroism from yellowish-brown with a tinge of green for vibrations across the length of prismatic sections to deep indigo-blue and opaque along the length, to which the a-axis of the indicatrix is nearly parallel. Accompanying the riebeckite, and in some cases wholly replacing it, is cossyrite: aegirine and also aegirine-augite are generally present, but in comparatively small amount. In a specimen from Green Mt., besides aegirine, which is scattered in small grains uniformly over the slide, and cossyrite, there occurs the hornblende with pleochroism from reddish-brown to deep bluish-brown or opaque described by Renard[1] as also occurring in crystals formed by sublimation in the crevices of the rock. In some of the other specimens this hornblende occurs with a zonal intergrowth of riebeckite. The phenocrysts in these rocks consist of sanidine, and of anorthoclase showing the characteristic minute twin-striations.

Some of these trachytes are strikingly similar to the riebeckite-trachytes from Senafé, Abyssinia, described in a previous paper[2]. That some of them should be referred to the soda-rhyolites is suggested by the results of the chemical analysis of Klement quoted by Renard[3].

In the following table this analysis of trachyte from Ascension is reproduced under I, while for comparison are given under II that of the comendite from Comende, Sardinia; under III that of Klement's analysis of obsidian from Ascension; under IV that of a quartz-keratophyre from the Mühlenthal; under V that of a pantellerite from Mt. S. Elmo, Pantelleria; and under VI that of the glassy soda-rhyolite from the Rift Valley described on p. 245.

	I.	II.	III.	IV.	V.	VI.
SiO_2 ...	70·99	74·76	72·71	70·97	69·02	70·61
TiO_2 ...	—	—	—	—	—	0·15
Al_2O_3 ...	14·84	11·60	12·80	13·84	10·09	8·59
Fe_2O_3 ...	3·76	3·50	2·64	3·21	4·42	2·52
FeO ...	0·35	0·19	1·48	0·78	4·56	5·96
MnO ...	trace	—	trace	0·12	—	0·34
CaO ...	0·60	0·07	0·58	1·26	1·45	0·61
MgO ...	0·14	0·18	0·10	0·20	0·76	0·07
Na_2O ...	5·94	4·35	6·50	6·27	6·29	6·77
K_2O ...	2·40	4·92	3·87	1·57	3·70	4·46
H_2O ...	0·40	0·64	0·48	0·74	—	0·10
	99·42	100·21	101·16	98·96	100·29	100·18

[1] Loc. cit., p. 53. [2] This Magazine, 1900, vol. xii, p. 94. [3] Loc. cit., p. 47.

The obsidians of Ascension, which are seen by the above analysis to be the glassy equivalents of the 'augite-trachytes,' have the chemical composition of soda-rhyolites. One specimen in the British Museum collection shows under the microscope small phenocrysts of anorthoclase in a glassy base crowded with felspar-microliths: one or two small grains of aegirine and aegirine-augite and one of olivine are also present.

The close connexion between these obsidians and comendites and quartz-keratophyres is seen from the above analyses. They differ from pantellerites and the obsidian from the Rift Valley for the most part only in their lower percentage of oxides of iron.

Aden.

Many of the trachytic and phonolitic rocks of Aden show some points of resemblance with the rocks of the Rift Valley. Thus a pale green glassy rock in the British Museum collection showing marked flow-structure has a remarkable similarity with some of the 'kenytes' from Mt. Kenya. Under the microscope it shows small phenocrysts of anorthoclase, with the twin-striations well marked, in a dense glassy base crowded with minute felspar-microliths, and interstitial irregular grains of aegirine-augite and opacite (suggestive of altered cossyrite): amongst the phenocrysts are one or two small crystals of aegirine-augite and, very sparingly, olivine.

Another specimen is a phonolitic quartz-trachyte similar to those from the Rift Valley (p. 242). In this rock small phenocrysts of sanidine and anorthoclase with, very sparingly, aegerine-augite and fairly large olivines occur in a trachytic mesh of felspar-laths with needles of grass-green aegirine, micropoecilitic quartz, and patches of ferrite and opacite very suggestive of altered cossyrite.

Abyssinia.

The general resemblance of phonolitic rocks from the neighbourhood of Axum and of Senafé, Abyssinia, to rocks from the Rift Valley and from St. Helena and Ascension has been sufficiently demonstrated in the preceding pages. In addition, two glassy rocks may be mentioned here as very similar to some of the spherulitic phonolitic obsidians of the Rift Valley. The specimens belong to the Blanford collection[1] and come, one from the Ferra Pass, near Belago, and the other from the

[1] The collection was made by Dr. W. T. Blanford when acting as geologist to the Abyssinian Expedition of 1868 under Sir Robert Napier.

Alagi Pass. They are deep-brown spherulitic glassy rocks showing flow-structure and phenocrysts of anorthoclase with a few pale green augites and, very sparingly, olivine.

General Conclusions and Summary.

Gneisses and schists with granulites form the basement rocks of British East Africa. Above them on the western side of the Great Rift Valley in the Victoria Nyanza region occur the ferruginous schists, shales, and sandstones of the Karagwe series, part of which may probably be referred to the Cape system of South Africa and the Cuddapah series of India. Through these ancient rocks in Tertiary times were erupted the lavas from Mts. Kenya, Kilimandjaro, and Elgon, and from the craters of the Rift Valley and those at the foot of Ruwenzori.

With the exception of basalts from Laikipia and Kamasia and of basic nephelinites and melilite-rocks from the Mt. Elgon district and Ruwenzori, the lavas are mainly of a phonolitic type: all have doubtless been derived from a soda-rich nepheline-syenite- or theralite-magma. They present a remarkable example of a *rock-series* varying in basicity from acid riebeckite-rhyolites to basic phonolites and kenytes, but with all the members characterized, chemically, by the low contents of lime and magnesia and high percentages of alkalies (especially soda) and oxides of iron, and mineralogically, by the presence of anorthoclase and for the most part of both soda-pyroxenes and soda-amphiboles.

In their characters these phonolitic lavas present striking analogies with eruptive rocks from other parts of Africa and the neighbouring islands. This is especially true of the rocks of Pantelleria, the Canary Islands, and Abyssinia; but the phonolitic rocks of St. Helena, Ascension, and Aden also have many features in common with those of British East Africa and Abyssinia. The eruptive rocks of Madagascar are mainly of a phonolitic type [1], and nepheline-syenites occur there, and also in the Transvaal and on the west coast of Africa on the Los Islands, Sierra Leone. Nephelinites and leucitites are also the principal lavas of the Etinde volcano in the Cameroons [2]. Altogether there would seem to be a wonderful uniformity about the eruptive rocks of Africa and the adjacent islands, indicating that they have all been derived from alkali-rich nepheline-syenite- or theralite-magmas.

[1] See Lacroix, Les roches alcalines caractérisant la province pétrographique d'Ampasindava. Nouv. Archives du Muséum d'Histoire Naturelle. Paris, 1902, sér. 4, tom. iv, fasc. 1, 152 pp., 10 pls.; and this Magazine, 1900, vol. xii, p. 272.

[2] E. Esch, Sitz.-Ber. Akad. Wiss. Berlin, 1901, pp. 277, 400.

This may be, however, only a part of a wider generalization, for the association of basalts with alkali-rich phonolitic rocks appears to be common not only to the west African islands, but to the great Atlantic volcanic chain generally. This association, for example, is met with not only in the islands of Ascension and St. Helena, but also in the islands of Fernando Noronha, the Little Island of Trinidad, and the Tristan d'Acunha group. Basalts are the prevailing rocks in the Faroe Islands and in Iceland, and in the latter locality they are associated with obsidians rich in alkalies and poor in lime and magnesia. In the Hebrides also the Tertiary basalts are associated with 'pitchstones,' many of which contain augite and anorthoclase and are thus related to pantellerites. The two European offshoots from the great Atlantic chain are also characterized to a large extent [1] by alkali-rich lavas associated with basalts. This is the case in the volcanic regions of Auvergne, the Eifel, and the Bohemian Mittelgebirge belonging to the northern branch; while in the southern Mediterranean branch the present basaltic eruptions are mainly of a type rich in alkalies, and the trachytic lavas have some points of resemblance (e. g. the Arso trachyte) with the 'acmite-trachyte' of Terceira and the rocks of the kenyte series [2]. To this Mediterranean branch belong also the soda-rich lavas of Pantelleria and the phonolites of Tripoli. The lavas of Santorin, however, appear to be connected with the andesitic eruptions of Asia Minor.

Thus of the four great volcanic chains running north to south, the great Atlantic chain with its European branches, and the minor chain along the east coast of Africa including Madagascar, are characterized by the association of basalts and alkali-rich phonolitic rocks, whereas in the two other great Pacific chains (one from Alaska through Japan and the East Indies to New Zealand, and the other down the western coast of the American continent) andesites are the prevailing lavas.

In this connexion it is of interest to recall the fact which has been noted that the eruptive rocks in the United States become more and more rich in soda as one proceeds from west to east, i. e. from the Pacific towards the Atlantic volcanic chain [3]. Similarly in Europe and Asia the lavas become less rich in alkalies and more andesitic in character (e. g. the Hungarian andesites and the andesitic lavas of Santorin and

[1] With the exception of the Hungarian andesites.

[2] The 'bread-crust' bombs of Lipari (the 'volcanite' of Hobbs, Zeits. Deutsch. Geol. Gesellschaft, 1893, vol. xlv, p. 578) are, by their mineral contents at least, more closely connected with the kenyte-series (pantellerites) than with the dacites.

[3] The lavas of the West Indies, however, as we have recently seen, still rather conform to the Pacific than to the Atlantic type.

Asia Minor) as one proceeds from west to east, i. e. from the Atlantic towards the Pacific volcanic chain.

To the basalt-phonolite type appear to belong the eruptive rocks of Kerguelen and of South Victoria Land in the Antarctic Ocean, where basalts are associated in the former locality with phonolites, and in the latter with phonolitic trachytes belonging to the kenyte series [1].

In New Zealand the two types appear to effect a junction, for whereas in the South Island at Dunedin occur basalts with phonolitic rocks similar to those of Cape Adare, in the North Island andesites are the prevailing lavas.

List of Localities.

In conclusion is appended a list of the principal districts in British East Africa from which the specimens described in the preceding pages were collected, with the names of the rocks [2].

Archaean Plateau (Lugard's Falls on the Sabaki River, Iveti Mts., &c.)	*Gneisses, granulites, and amphibolites.*
Athi and Kapte Plains	*Phonolites.*
Kikuyu . . .	*Phonolites, phonolitic trachytes, obsidians, and kenytes.*
Laikipia . . .	*Phonolites, phonolitic trachytes, kenytes, and basalts.*
Baringo District (Kamasia)	*Phonolites, phonolitic trachytes, and basalts.*
Mau District, including Lake Naivasha, Nakuru, &c.	*Phonolites, phonolitic trachytes, riebeckite-rhyolites, and pantellerites.*
Nandi District .	*Phonolites, melilite-nephelinites, granite, and gneiss.*
Mt. Elgon . . .	*Nephelinites, tuffs, and rocks related to borolanite and jacupirangite.*
Elgon District .	*Gneisses, granites, and diabase.*
Busoga	*Ferruginous schists, shales and sandstones, quartzite, granite, diabase, pegmatite, laterite and ironstone.*
Bukedi	*Gneiss and schist, granite, pegmatite, quartzite.*

[1] See Prior, Report on the Rock-specimens, p. 328, in Report on the Collections of Natural History made in the Antarctic Regions during the voyage of the 'Southern Cross.' London, 1902.

[2] A list, with localities, of the specimens in Sir Harry Johnston's collections from Uganda, is given in his book 'The Uganda Protectorate.' London, 1902.

Uganda Province	*Ferruginous shales and sandstones, quartzite, phyllite, diatomaceous earth* (8 *miles west of Katonga River*).
Ankole	*Phyllites, ferruginous shales and sandstones, and basalt scoria.*
Toro (Ruwenzori)	*Gneiss, schists, epidiorite, nephelinite with perofskite, tuffs.*
Unyoro . . .	*Ferruginous schists, shales, and phyllites; sandstone, quartzite, gneiss, and granulite.*
Nile Province .	*Gneiss and basalt.*

EXPLANATION OF PLATE V.

Microscope-sections of rocks from British East Africa.

Fig. 1.—Garnet-hornblende-granulite from five days west of Hameye (p. 230).
Pink garnet and green hornblende in a groundmass of plagioclastic felspar.
Magnification 10 diam., 2 inch objective.

Fig. 2.—Phonolite from Doenyo lol Mwaru (p. 238).
Portion of the groundmass highly magnified, showing grass-green aegirine, smoky rose-red catophorite, and nearly opaque reddish-brown cossyrite.
Magnification 100 diam., $\frac{1}{4}$ inch objective.

Fig. 3.—Phonolite from south of Lari lol Morjo (p. 238).
Small colourless sanidines, and tufts of green aegirine, deep red-brown cossyrite, and some catophorite in a groundmass of felspar-microliths and altered nepheline.
Magnification 20 diam., 1 inch objective.

Fig. 4.—Phonolite from Kamnye River (p. 238).
Phenocrysts of sanidine and nepheline, and patches of grass-green aegirine, deep brown cossyrite, and sky-blue amphibole near to riebeckite.
Magnification 10 diam., 2 inch objective.

Fig. 5.—Phonolite with melanite, allied to borolanite, from Mt. Elgon (p. 253).
Phenocrysts of nepheline, green aegirine-augites with terminations of aegirine, and deep-brown melanite.
Magnification 10 diam., 2 inch objective.

Fig. 6.—Rock allied to jacupirangite from Mt. Elgon (p. 253).
Yellow augite, purple perofskite, and magnetite.
Magnification 10 diam., 2 inch objective.

The plate has been executed at the Oxford University Press by the three-colour collotype process from a water-colour painted by Miss E. Drake. On the whole the original colours have been fairly well reproduced, although not with absolute truthfulness.

Some new crystal-forms on Krennerite.

By G. F. Herbert Smith, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read June 10, 1902.]

SOME interest attaches to crystals of krennerite, since this mineral has apparently the same composition as calaverite, the crystalline development of which presents such peculiar features. After completing the study of crystals of the latter substance, the author naturally turned his attention to krennerite to ascertain whether any similar peculiarities were noticeable, but nothing abnormal could be detected.

Good crystals of krennerite are rare. The Mineral Collection of the British Museum has however a specimen from Nagyág, on which are dotted numerous small crystals possessing a large number of brilliant faces. This specimen was examined by Prof. H. A. Miers rather more than twelve years ago, and the measurements of one good crystal are recorded in this Magazine [1]. The author measured the same crystal and four other smaller crystals on the three-circle goniometer designed by him, and encountered a large number of minute faces representing forms hitherto unrecorded. The habit of the crystals is prismatic, the prism-zone being striated, and the colour is a bronze-yellow. The cross-section of the measured crystals varies from $0{\cdot}2 \times 0{\cdot}2$ to $0{\cdot}7 \times 0{\cdot}5$ mm.

The author has observed on these crystals all the forms previously recorded and in addition the following, which are new:— K (310), L (520), M (650), N (340), j (140), J (160), β (141), γ (582), f (231), α (562), r (142), x (342), y (221), R (542), δ (043), ϕ (343), ϵ (032), θ (054), χ (144), ψ (344), ξ (411), η (012), κ (013), λ (901), π (401), Π (502), and μ (104).

[1] 1890, vol. ix, pp. 184–6.

Fig. 1 is reproduced from Prof. Miers's paper [1]. Fig. 2 illustrates the occurrence of some new faces on one of the smallest crystals measured.

In the table (p. 266) are given the calculated and the mean observed values of the distances and azimuths of the forms, when measured from a (100).

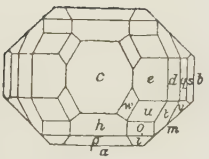


Fig. 1.

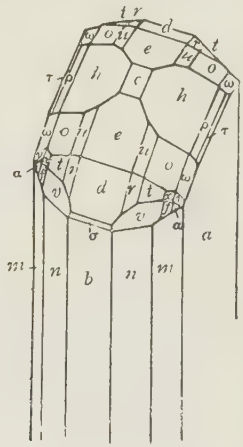


Fig. 2.

Krennerite.

The axial ratios are :—$a : b : c = 0{\cdot}9369 : 1 : 0{\cdot}5068$.

For comparison the ratios determined by previous observers are added :—

Vom Rath [2]	$a : b : c = 0{\cdot}9407 : 1 : 0{\cdot}5045$,
Schrauf [3]	$a : b : c = 0{\cdot}9396 : 1 : 0{\cdot}5073$,
Miers [4]	$a : b : c = 0{\cdot}9389 : 1 : 0{\cdot}5057$.

[1] The form (041), denoted by s in the figure, is called σ in the present paper, because the former letter has been assigned to (130) in accordance with the notation adopted in Dana's 'System of Mineralogy,' 6th edition.

[2] Zeits. Kryst. Min., 1877, vol. i, pp. 614–17.

[3] Zeits. Kryst. Min., 1878, vol. ii, pp. 235–9.

[4] Loc. cit.

TABLE.

Measurements from *a* (100).

Form.		Calculated Values.		Observed Means.		Edges.	Limits of Observation.		Remarks. Characters of faces and images.
		Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.	
		° ′	° ′	° ′	° ′		° ′ ° ′	° ′ ° ′	
a	100	*	*	0 0	0 0	9	... ...	... ...	Large; images good.
K	310	,,	17 20½	,, ,,	18 3	2	... ...	17 55, 18 11	Minute.
L	520	,,	20 32½	,, ,,	20 31	2	... ...	20 30, 20 32	,,
k	210	,,	25 6	,, ,,	26 4	1	... ...	... ...	,,
l	320	,,	31 59	,, ,,	32 7	7	... ...	31 18–32 48	Small.
M	650	,,	37 59	,, ,,	38 22	1	... ...	... ...	Minute.
m	110	,,	*	,, ,,	43 8	12	... ...	42 49–43 28	Large; images good.
N	340	,,	51 19	,, ,,	51 25	1	... ...	... ...	Minute.
n	120	,,	61 55	,, ,,	61 55	12	... ...	61 24–62 39	Small; images fair.
s	130	,,	70 25	,, ,,	71 0	1	... ...	... ...	Striated.
j	140	,,	75 4	,, ,,	75 57	2	... ...	75 54, 76 0	,,
J	160	,,	79 55	,, ,,	80 20	1	... ...	... ...	,,
b	010	,,	90 0	,, ,,	90 0	9	... ...	... 90 6	Small; images fair.
γ	582	26 15½	59 6½	26 8	58 10	1	... ...	... ...	Minute.
β	141	,, ,,	76 32½	26 15	76 15	1	... ...	... ...	,,
σ	041	,, ,,	90 0	,, ,,	90 0	2	... ...	... 90 4	Small.
a	562	33 20	53 23	33 18	53 29	4	33 2–33 24	53 19–53 38	Minute.
f	231	,, ,,	59 16	,, ,,	59 29	1	,, ,,	... ...	,,
v	362	,, ,,	65 58	,, ,,	66 1	5	,, ,,	65 48–66 20	Small.
q	031	,, ,,	90 0	,, ,,	90 0	4	,, ,,	... 90 2	,,

		44 47	46 28½	44 35½	46 35	1	44 20–44 47	... ...	... ...	Minute.
y	231	,, ,,	52 46	,, ,,	52 43	2	,, ,,	52 29, 52 57		Small.
x	342	,, ,,	60 19	,, ,,	60 23	4	,, ,,	60 14–60 31		,,
t	121	,, ,,	69 12	,, ,,	69 11½	5	,, ,,	69 0–69 18		,,
r	142	,, ,,	79 15	,, ,,	79 13	4	,, ,,	79 0–79 23		,,
d	021	,, ,,	90 0	,, ,,	90 0	5	,, ,,	... 90 4		,,
ϵ	032	52 45½	90 0	52 26	90 3	1	... ...	... ...		Minute.
ϕ	343	55 57	65 51½	55 0	67 0	1	... ...	... ...		,,
δ	043	,, ,,	90 0	,, ,,	90 0	1	... ...	... ...		,,
θ	054	57 39	90 0	58 0	90 0	1	... ...	... ...		,,
ξ	411	*	27 23½	63 7½	28 0	1	62 55–63 15	... ...		,,
ζ	522	,,	39 39½	,, ,,	40 0	1	,, ,,	... ...		,,
ω	211	,,	46 1	,, ,,	46 9	5	,, ,,	45 27–46 45		Small; images fair.
i	322	,,	54 6	,, ,,	54 9	10	,, ,,	53 57–54 20		,, ,,
o	111	,,	64 14½	,, ,,	64 17	6	,, ,,	64 9–64 28		,, ,,
ψ	344	,,	70 6½	,, ,,	70 30	1	,, ,,	... ...		Minute.
u	122	,,	76 26	,, ,,	76 31½	18	,, ,,	76 20–76 53		Large; images good.
χ	144	,,	83 7	,, ,,	82 45	1	,, ,,	... ...		Minute.
e	011	,,	90 0	,, ,,	90 0	7	,, ,,	... 90 4		Large; images fair.
w	124	75 47	82 32	75 45	82 25	1	... ...	... ...		Small.
η	012	,, ,,	90 0	76 0	90 10	1	... ...	... ...		Minute.
κ	013	80 25	90 0	80 10	90 0	1	... ...	... ...		,,
λ	901	90 0	11 36	90 0	11 37	2	... 90 11	11 30, 11 44		,,
π	401	,, ,,	24 48½	,, ,,	25 9	3	... ,,	24 40–25 28		,,
τ	301	,, ,,	31 38½	,, ,,	31 35	6	... ,,	31 0–31 53		Small.
Π	502	,, ,,	36 29	,, ,,	36 48	1	... ,,	... ...		Minute.
ρ	201	,, ,,	42 45	,, ,,	42 41	4	... ,,	42 20–42 55		Small.
h	101	,, ,,	61 35½	,, ,,	61 35	10	... ,,	61 23–61 50		Minute.
g	102	,, ,,	74 52	,, ,,	75 20	2	... ,,	75 15, 75 35		,,
μ	104	,, ,,	82 18	,, ,,	82 36	1	... ,,	... ...		,,
c	001	,, ,,	90 0	,, ,,	90 0	5	... ,,	... 90 3		Large; image good.

Mineralogical notes on Western Australian Tellurides: the non-existence of 'Kalgoorlite' and 'Coolgardite' as mineral species.

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SINCE the occurrence of tellurides of gold in Western Australia was first recognized by Mr. Arthur G. Holroyd[1] in May, 1896, these minerals have proved to be of the greatest importance as a source of gold; and in fact the telluride mines at Kalgoorlie in the East Coolgardie gold-field now yield as much gold as all the remaining gold-fields of Western Australia taken together.

Although the occurrence of traces of telluride of gold has been reported from one or two other localities in the neighbouring portions of Western Australia, it is only in a quite small area around Kalgoorlie that the tellurides are mined. Here they occur as lodes, or rather as large lenticular masses and as impregnations, in schistose rocks. It is only, however, below a certain depth that the tellurides are found; nearer the surface, where the rocks have been weathered and altered, these minerals have been decomposed with the separation of native gold.

The tellurides occur in irregularly bounded crystalline masses, and unfortunately appear never to have been found as crystals with plane surfaces. The discovery of such crystals would be full of interest from a scientific point of view, and would afford a solution of many problems, which must, for the present, be left undecided. With the occurrence of such large crystalline masses of tellurides there can be little doubt but that one day crystals will be found; and these will probably surpass those hitherto obtained from other parts of the world. Cavities in the ore appear to be only rarely present, and when these are met with they should be searched for crystals.

[1] For references to original papers see p. 289 below.

In the present paper are given the results of a purely mineralogical examination of the specimens of Western Australian tellurides preserved in the mineral collection of the British Museum. In this collection there are 129 samples of gold-ores and auriferous specimens from Western Australia, of which sixty-five came from Kalgoorlie; tellurides[1] are present on forty-eight of the Kalgoorlie specimens, which have been acquired at various times since 1897. I have also had opportunities of inspecting many other specimens of Western Australian tellurides at the London offices of some of the gold-mining companies and at the Colonial Exhibition in London in 1902, but have seen nothing essentially different from the British Museum specimens to be described below.

The whole of this rich material, with the exception of only two specimens, has been presented to the Trustees by the several gold-mining companies, by the Government of Western Australia, through the Royal Commission appointed for the exhibition of the products of that State, and by various private individuals. Many of the specimens thus made available for examination by the generosity of the various donors are of considerable intrinsic value. A large proportion of this material had been specially collected by Mr. A. G. Holroyd, the Mineral Curator of the exhibits, for the Paris Exhibition of 1900; previous to this it had been shown at the Coolgardie Exhibition of 1899, and subsequently at the Glasgow Exhibition of 1901, and at a small Colonial Exhibition at the Royal Exchange in London in 1902. At the close of the last exhibition an immense amount of valuable material, including numerous large, showy masses of native gold and gold telluride, was sent by the owners to be converted into bullion. In 1900, Mr. L. Fletcher, F.R.S., Keeper of Minerals in the British Museum, after inspecting the mineral specimens at the Paris Exhibition, called the attention of Mr. Holroyd and of the exhibiting companies to the importance to science of the permanent preservation of specimens illustrative of the modes of occurrence of gold in Western Australia, and as a result was promised, for the British Museum, the gift of various specimens as soon as they should be no longer required by the companies for the purpose of exhibition. In 1902, during the last days of the Colonial Exhibition in London, Mr. Fletcher personally interviewed the

[1] Besides the Kalgoorlie tellurides, there are specimens of tetradymite (bismuth telluride) with native gold in white quartz from the Dunallan No. 1 gold-mine near Coolgardie in the Coolgardie gold-field, which were presented to the Museum by Mr. A. O. Watkins in 1895.

Hon. H. W. Venn, President of the above-mentioned Royal Commission, and the Hon. H. B. Lefroy, Agent-General for Western Australia and formerly Minister of Mines, and enlisted the active sympathy of both; a large series of specimens, enthusiastically selected by Mr. Holroyd, who was familiar with their peculiarities, was thus saved from destruction, and was presented by the owners to the Trustees of the British Museum.

Calaverite. This is the most abundant and the richest in gold of all the tellurides, and was also the first to be discovered at Kalgoorlie. It is easily recognizable by its pale bronze-yellow colour with bright metallic lustre, and its sub-conchoidal fracture with absence of cleavage. It somewhat resembles iron-pyrites in appearance, and in fact some of the material found by Mr. Holroyd in 1896 had actually been thrown away as such on the waste-heaps.

The mineral occurs sometimes in masses of considerable size, as is shown by a very large specimen (No. 86066) in the British Museum. This mass, from the Associated Gold Mines of Western Australia, is said to be the largest that has been raised. With the matrix of greenish schist it weighs 180 pounds, and over the whole of one surface, measuring about 63×18 cm. (25×7 inches), there is a thick deposit of various tellurides; the calaverite, however, predominates in amount, being in one place continuous over an area of 40×15 cm.

When calaverite is heated on charcoal in the oxidizing flame of the blowpipe, the tellurium it contains is readily oxidized, giving rise to dense white fumes and imparting a bright bluish-green colour to the flame, a bead of gold being left behind. When heated in a bulb-tube, calaverite gives a black sublimate of metallic tellurium, and a less volatile sublimate of drops of tellurous oxide (TeO_2), which is yellow when hot and white or colourless when cold; a yellow malleable bead of gold is not obtained in this way. During the cooling of the beads so obtained, either on charcoal or in the bulb-tube, the interesting phenomenon of *recalescence* was sometimes observed—after a red-hot bead had become dark it suddenly and momentarily again flashed out red and glowing. This behaviour, which was also exhibited by beads obtained from sylvanite, appeared to depend on the presence of a small amount of tellurium still remaining in the bead.

Several chemical analyses have been made of the calaverite from Kalgoorlie, and these, for convenience of reference and comparison, are collected together below. The calculated percentage composition corresponding to the formula $AuTe_2$ is given at the head of the list.

Analyses of Calaverite from Kalgoorlie.

Analyst.	Te.	Au.	Ag.		Total.	Sp. gr.
$AuTe_2$	56·3	43·7	—		100·0	—
Holroyd (1897) . .	55	44	trace		99	—
,, . . .	54	39·2	3		96·2	—
Mingaye (Pittman, 1897)	56·65	41·76	0·80		99·21	9·377
Simpson (1898) . .	57·27	41·37	0·58		99·22	9·311
Rogers (quoted by Simpson, 1898) . . .	59·69	38·70	1·66	Cu, 0·21; Fe, 0·18; S, 0·09; Pb, Bi, Zn, traces.	100·53	—
Klüss (Krusch, 1901) .	58 63	37·54	2·06	Cu, 0·29; Fe, 0·09; Ni, 0·07; Se, 1·13; S, 0·10; gangue, 0·23.	100·14	—
Carnot (1901) . .	60·30	33·90	4·82	Cu, 0·63; Fe, trace .	99·65	—
McGeorge (quoted by Simpson, 1902) . .	54·1	42·6	0·7	Arsenopyrite, 2·4 .	99·8	—
MacIvor (1902) . .	57·00	42·15	0·60		99·75	9·314

Sylvanite. This is of much less frequent occurrence at Kalgoorlie than the other tellurides containing gold. It is recognizable by its silver-white colour with brilliant metallic lustre and its perfect cleavage in one direction. It occurs in masses of some size, much larger than those from Transylvania and Colorado; thus one of the British Museum specimens shows the perfect cleavage uniform in direction through a mass 8 cm. in length, and another mass measures $4\frac{1}{2}$ cm. in a direction perpendicular to the cleavage. These large crystalline individuals show no plane crystal-faces, but sometimes, on their rough, striated exterior, there are unmistakable indications of twinning about a plane perpendicular to the direction of cleavage.

It is, however, to be noted that the silver-white colour and the single perfect cleavage are characters possessed by krennerite as well as by sylvanite. Both minerals are further referable to the same type of chemical formula, namely $(Au,Ag)Te_2$; but while sylvanite appears to be fairly constant in composition, approximating to the formula $AuAgTe_4$, krennerite on the other hand varies considerably, the amount of silver, for example, having been given at 0·46, 5·87, and 19·44 per cent. in different analyses of material from Transylvania and Colorado. It would thus be only possible to distinguish with certainty between these two species when crystals are available for the determination of their symmetry, sylvanite being monoclinic and krennerite orthorhombic.

The silver-white, cleavable gold and silver telluride of Kalgoorlie may thus be either sylvanite or krennerite, or possibly both. Under the circumstances it appears best, for the present, to refer to it as sylvanite, since krennerite has as yet been found only in minute crystals which are not twinned. Again, the krennerite of Transylvania and Colorado is described as decrepitating violently when heated before the blowpipe: none of the Western Australian material in the British Museum behaves in this way, but fuses readily and quietly.

Attention may be called here to a statement by Mr. E. S. Simpson (1898, p. 48): he mentions 'small rhombic crystals with deep vertical striations of a telluride of gold, perhaps Krennerite,' as being associated with calaverite, coloradoite, and native gold on a specimen from the Kalgurli mine. This observation, if correct, is of some importance, but no mention of it is made by Mr. Simpson (1902) in his collected notes on Kalgoorlie tellurides: moreover, cleavable telluride is also referred by him to calaverite and goldschmidtite[1].

Of the analyses quoted below, three approach the formula $AuAgTe_4$, while the first, in containing much less silver, is quite distinct: for this reason the material analysed by Dr. Frenzel has been referred by Professor Hintze[2] to krennerite.

Analyses of Sylvanite (and Krennerite?) from Kalgoorlie.

Analyst.	Te.	Au.	Ag.		Total.	Sp. gr.
$AuAgTe_4$	62·5	24·2	13·3		100·0	—
Frenzel (1897) . .	58·63	36·60	3·82		99·05	8·14
Wölbling (Krusch, 1901)	60·83	28·55	9·76	Cu, 0·32; Fe, 0·06; Ni, 0·10; Se, 0·20; S, 0·09; gangue, 0·05.	99·96	—
Carnot (1901) . .	60·45	29·85	9·18	Cu, 0·15; Ni, 0·10	99·73	—
Higgin (quoted by Simpson, 1902) . . .	54·50	36·95	8·30		99·75	—

Petzite. This is readily distinguished from the other gold and silver tellurides by its iron-black colour with metallic lustre and the marked conchoidal fracture with absence of cleavage. It is, however, absolutely indistinguishable in appearance from the mercury telluride, coloradoite;

[1] Goldschmidtite was described in 1899 as a gold and silver telluride from Colorado, but was proved the following year to be identical with sylvanite.

[2] Handbuch der Mineralogie, 1901, vol. i, p. 898.

and it also resembles more or less closely another Kalgoorlie mineral to be mentioned below, namely, fahlerz.

When heated on charcoal in the oxidizing flame of the blowpipe, petzite produces only slightly the bluish-green colouration of the flame and the dense white fumes characteristic of tellurium; only when fused with sodium carbonate does it give a white malleable bead, and this when placed in nitric acid becomes yellow. Calaverite and sylvanite, on the other hand, are much less stable, and are readily converted into a bead of gold by simply heating on charcoal in the oxidizing flame; this, however, takes place much more readily with calaverite than with sylvanite, since the latter contains more silver in combination with the tellurium.

The analyses quoted below agree closely, like the analyses of petzite from other localities, with the formula $(Ag,Au)_2Te$, in which $Ag : Au = 3 : 1$; the formula may therefore be written as $3Ag_2Te \cdot Au_2Te$ or Ag_3AuTe_2.

Analyses of Petzite from Kalgoorlie.

Analyst.	Te.	Au.	Ag.		Total.
Ag_3AuTe_2	32·8	25·4	41·8		100·0
Wölbling (Krusch, 1901)	32·60	24·33	40·70	Cu, 0·10; Fe, 0·07; Ni, 0·08; Se, 1·45; S, 0·26; gangue, 0·12.	99·71
Carnot (1901) . .	31·58	23·58	13·31	Hg, 0·88; Cu, 0·20; Fe, trace; Sb, 0·30.	99·85
„	32·33	24·16	41·22	Hg, 2·00; Cu, 0·10 . .	99·81
„	33·00	23·42	41·37	Hg, 2·26; Cu, 0·16 . .	100·21
Grace (quoted by Rickard, 1901) . . .	34·60	24·64	40·47	Hg, 0·29	100·00
„ „	34·83	24·62	40·55		100·00

The mercury shown in these analyses, especially in two by Professor Carnot, is no doubt due to the presence of coloradoite as an impurity (cf. p. 284).

Two other analyses, not quoted above, of gold and silver telluride from Kalgoorlie are given by Dr. Krusch[1] and by Professor Carnot[2]. The formulae corresponding to these analyses may be split up as follows:—

$$(1) \quad (Ag,Au)_5Te_3 = 2\tfrac{1}{3}\,(Ag,Au)_2Te + \tfrac{1}{3}\,(Au,Ag)Te_2,$$

$$(2) \quad (Ag,Au)_4Te_3 = 1\tfrac{2}{3}\,(Ag,Au)_2Te + \tfrac{2}{3}\,(Au,Ag)Te_2,$$

	Te.	Au.	Ag.	Hg.	Cu.	Fe.	Ni.	Zn.	Sb.	S.	Gangue.	Total.
[1]	36·90	15·06	45·95	—	1·16	0·08	0·06	0·04	0·12	0·45	0·22	100·04
[2]	41·11	26·10	30·43	0·70	0·60	0·40	—	—	0·80	—	—	100·14

suggesting that the substances analysed were probably mixtures of petzite and calaverite. It should be noted, however, that the percentage of silver given by Dr. Krusch is higher than in any of the petzite analyses quoted above, and this may indicate the presence of hessite (see p. 282). Professor Carnot himself suggests that the material he analysed was a mixture.

All these analyses of Western Australian tellurides have of necessity been made on massive material, and in no case does it appear that special precautions were taken to collect pure material all of one kind. Accurate analyses of carefully selected and measured crystals are desirable.

It seems probable that in these tellurides the gold and silver do not isomorphously replace each other, as is usually considered to be the case, but that they are present in atomic proportions, as indicated in the formulae adopted above. These formulae may represent double tellurides or possibly simple salts (perhaps tellur-aurates, analogous to sulph-antimonites).

Coloradoite. This telluride of mercury, with its iron-black colour and well-marked conchoidal fracture, is identical in appearance with petzite, from which it can only be distinguished by chemical tests. In fact, it has no doubt previously been mistaken for petzite, and, as will be shown below, a mixture of coloradoite and petzite has been described as a supposed new mineral species under the name 'kalgoorlite.'

Only two of the several authors (Rickard and Simpson) writing on Western Australian tellurides have mentioned coloradoite as being present on the specimens examined by them; and it has been considered to be of rare occurrence. In reality, however, it is comparatively abundant, for of the forty-eight Western Australian telluride specimens in the British Museum, coloradoite is present on twenty-eight.

In the examination of these specimens ninety-nine fragments of coloradoite were separately determined. This can be done very readily and quickly by heating on charcoal before the blowpipe or in a bulb-tube; in each case the reactions are quite distinct from those of petzite (and of fahlerz, which also somewhat resembles coloradoite in appearance). On charcoal the mineral readily fuses and colours the flame bright bluish-green, emits dense white fumes, and in a very short time completely disappears. In the closed tube it fuses with spluttering to a black globule, and gives a sublimate of globules of mercury and a much less volatile sublimate of

drops of tellurous oxide, the latter being yellow when hot and white or colourless when cold; with a larger fragment of material a black sublimate of metallic tellurium is also obtained.

The only quantitative analysis made on Western Australian coloradoite is by Mr. E. S. Simpson (1899), who obtained the results quoted below. The same author had previously (1898) given the specific gravity of another sample of material as 9·21.

Hg.	Ag.	Au.	Te (by difference).
50·40	0·12	trace	[49·48].

These numbers give the formula Hg_2Te_3, and not HgTe, the accepted formula for coloradoite deduced by Professor F. A. Genth for the Colorado mineral discovered by him in 1877. The material analysed by Professor Genth was, however, very impure, containing admixed quartz, gold, sylvanite, and native tellurium up to nearly 50 per cent.; but the heavier portions obtained by levigation contained more mercury and less tellurium, and approximated more closely to the formula HgTe. The Colorado material was therefore scarcely suitable for establishing the formula of the mineral, while on the other hand the formula proposed by Mr. Simpson is based only on a single mercury determination. It therefore seemed desirable to make a new analysis, especially as a large amount of pure material was available for this purpose.

The specimen (Brit. Mus. No. 85221) chosen from which to collect material for the present analysis was one on which no petzite or fahlerz had been detected. The only other telluride[1] observed is sylvanite, which shows a brilliant cleavage surface several centimetres across, and could not possibly have been confused with the coloradoite. The bright coloradoite shows excellent conchoidal fractures over comparatively large areas, in one case 2 × 2 cm., and in every way seems to be quite pure. The matrix of the specimen, which is from the Great Boulder Main Reef gold-mine at Kalgoorlie, is a green schist interbanded with white granular dolomite; quartz and iron-pyrites are also present.

Three separate lots of material were collected from the same part of this specimen. In detaching material it usually broke up into quite

[1] To be quite accurate, there was afterwards detected a small compact mass, which, from its appearance under the microscope and its behaviour before the blowpipe, probably consists of an intimate intermixture of petzite and sylvanite. This was the single case in which there was any doubt in the determinations. It is here of no moment, since it is quite separate from the coloradoite and could not possibly have been confused with this.

small fragments. Each of these fragments was examined under a lens on a sheet of white paper and in a good light, being turned about with a needle mounted in a handle. Each fragment on which the bright conchoidal fracture was interrupted was then separately picked up and again examined under a microscope, the one-inch objective of which is fitted with a lieberkuhn. Further, of the material so collected, twenty-one fragments were examined by heating on charcoal or in a bulb-tube to make certain that no petzite was present and that all was coloradoite.

The coloradoite so collected for analysis was of an iron-black colour with bright metallic lustre, and was quite opaque. It had an excellent conchoidal fracture with no indication of cleavage. The streak was black and shining. The mineral was rather brittle, but extremely friable. Hardness, $2\frac{1}{2}$. The specific gravity was determined with a 3 c.c. pycnometer on the three lots of material with the following results (reduced to water at 4°C.) :—

	Sp. gr.	Weight of material used.
	8·074	2·0505 gram.
	8·077	1·7032 ,,
	8·062	1·2911 ,,
Mean	8·07	

This result differs considerably from previous determinations. Mr. Simpson gives for the Kalgoorlie coloradoite the value 9·21; and Professor Genth gives 8·627 for the Colorado mineral after allowing for the large amount of impurities present.

The following are the results of one complete, and one incomplete, analysis, together with the calculated percentage composition corresponding to the formula HgTe :—

	I.	II.	HgTe.
Hg	60·95	59·4	61·2
Te	39·38	35·8	38·8
	100·33		100·0

In analysis I, 1·2833 gram of powdered material was decomposed with nitric acid; the decomposition took place readily and completely, and after expelling nitric acid, the residue was completely soluble in water and hydrochloric acid; gold and silver were therefore absent. The sulphides, precipitated by hydrogen sulphide, were separated by digestion with hot, yellow ammonium sulphide, and the insoluble mercury sulphide dried at 100°C. (HgS, 0·9074 gram). The tellurium

was precipitated in the metallic state from a boiling hydrochloric acid solution by ammonium bisulphite and dried at 100°C. (Te, 0·5054 gram).

These results are confirmed by another analysis previously made, in which more direct determinations were attempted. The behaviour of the mineral when heated in a bulb-tube suggested that, if heated in a combustion-tube in a current of air, metallic mercury and tellurium dioxide could be weighed separately. Under these conditions, however, the tellurium was not completely oxidized, and part of it volatilized with the mercury. The same also happened when the mineral was heated with sodium carbonate. The powdered material (anal. II, 2·1091 grams) was therefore mixed with a little potassium nitrate and an excess of sodium carbonate and heated in a combustion-tube, at the closed end of which sodium bicarbonate had been placed to expel the last traces of mercury. A globule of mercury (Hg, 1·2536 gram) was collected under water; as, however, some nitrous fumes were evolved, the mercury was slightly attacked in the cool part of the tube. The residue in the tube was dissolved in hydrochloric acid and the tellurium precipitated by ammonium bisulphite (Te, 0·7546 gram), but it was afterwards found that the precipitation was not quite complete.

These analyses conclusively prove that the formula of coloradoite is HgTe, and not Hg_2Te_3 as suggested by Mr. Simpson. The formula HgTe is the one to be expected from the relation of coloradoite to metacinnabarite (HgS) and tiemannite (HgSe). These minerals, which resemble coloradoite in their black colour and absence of cleavage, have been found as tetrahedral-cubic crystals, and it is probable that crystals of coloradoite when met with will be found to have the same symmetry. As shown in the following table there is an anomaly, for which no explanation can be given, presented by the specific gravity of this group of isomorphous minerals, the specific gravity of coloradoite being less than that of tiemannite, instead of greater, as is to be expected.

	Formula.	Crystal-class.	Sp. gr.
Metacinnabarite.	HgS	Tetrahedral-cubic	7·81 (Penfield)
Tiemannite . .	HgSe	Ditto	8·19 ,,
Coloradoite . .	HgTe	Ditto ?	8·07

The determinations of Mr. E. S. Simpson, namely, the formula Hg_2Te_3 and sp. gr. = 9·21 (which it must be remembered were not both determined on the same sample of material), led him to consider whether the mercury telluride of Kalgoorlie he examined was identical or not with

that of Colorado. Though of course it is possible that other mercury tellurides besides coloradoite (HgTe) may occur in nature, it will be best, for the present, to consider all the Kalgoorlie material to be coloradoite, as does Mr. Simpson himself.

Altaite. This mineral, the cubic lead telluride (PbTe), which has not hitherto been recorded from Western Australia, was found in small amount on three of the British Museum specimens, all from the Great Boulder Proprietary gold-mine. It is of a lead-grey colour, sometimes with a yellowish tarnish, and has three perfect cleavages at right angles to each other; measurements of the cleavage angles on the goniometer gave approximately 90°. In appearance it resembles galena, but qualitative chemical tests, both before the blowpipe and in the wet way, proved the presence of lead and tellurium and the absence of sulphur.

It may be useful to place on record, in the following table, the various tellurides which were found more closely associated together, i. e. on the same specimen, and the several mines from which they come. This table is, however, only complete so far as concerns specimens now preserved in the British Museum collection.

Of these forty-eight specimens, calaverite is present on twenty-nine, sylvanite on ten, petzite on fourteen, coloradoite on twenty-eight, and altaite on only three. More than one kind of telluride is shown by twenty-five of the specimens, and on eleven there are three kinds.

The minerals found in association with the tellurides on the British Museum specimens now remain to be briefly described.

Gold. Native gold is more abundant in the upper, oxidized portions of the lodes, having here resulted by the decomposition of the tellurides. This secondary gold is present in a finely divided state: when in loose, finely crystallized aggregates it is known as 'sponge-gold'; when dull and lustreless, with quite the appearance of yellow ochre, it is known as 'mustard-gold'; and when in bright films as 'paint-gold.' A large quantity, about 70 pounds, of specially fine and pure 'sponge-gold' was found in a single pocket in the Great Boulder Proprietary gold-mine; this consists of a cellular aggregate of minute crystals of gold, which, when examined under the microscope, appear to be cubo-octahedra.

Films of secondary gold are also present on one or two of the telluride specimens; but most of the native gold which occurs actually intermixed with the tellurides appears to be of primary origin and to have been deposited at the same time as the tellurides themselves. This

Specimen No. (Brit. Mus.).	Gold-mine at Kalgoorlie, W. A.	Calaverite.	Sylvanite.	Petzite.	Coloradoite.	Other minerals present.
83433	(Not stated) . . .	×			×	(Quartz, iron-pyrites, sericite, chlorite, and dolomite on most specimens.)
83636 *a*	Lake View Consols . .	×				
83636 *b*	,, ,, . .	×				
83637	,, ,, . .		×			
83638	,, ,, . .	×				
83639	,, ,, . .	×				} Films of secondary gold.
83640	,, ,, . .	×	×			
86002	,, ,, . .		×			
85932	Hannan's Block 45 . .	×				Calcite.
85217	Great Boulder Main Reef		×			
85218	,, ,,		×			Fahlerz.
85219	,, ,,		×		×	Fahlerz.
85220	,, ,,		×	×		
85221	,, ,,		×		×	
85980	,, ,,	×		×	×	
85344	Great Boulder Proprietary	×		×		
85345	,, ,,				×	Gold.
85958	,, ,,				×	
85959	,, ,,	×			×	
85960	,, ,,	×			×	Gold.
85961	,, ,,				×	Gold.
85962	,, ,,				×	Gold.
85963	,, ,,	×			×	Altaite.
85964	,, ,,	×				
85965	,, ,,			×		
85967	,, ,,	×		×	×	
85969	,, ,,	×			×	
85970	,, ,,	×			×	
85971	,, ,,	×		×	×	
85972	,, ,,	×		×		Altaite.
85973	,, ,,	×			×	Altaite.
85974	Great Boulder Perseverance				×	{ Chalcopyrite. { Gold.
85977	,, ,,				×	Gold.
85978	,, ,,				×	Gold.
85979	,, ,,	×	×	×		
85981	Associated Gold Mines, W.A.	×			×	Gypsum.
85983	,, ,,		×		×	
86066	,, ,,	×		×	×	Fahlerz.
85984	Associated Northern Blocks			×		Gold.
85985	,, ,,	×				Gold.
85991	Ivanhoe Gold Corporation	×				Chalcopyrite.
85993	Golden Horse-Shoe Estates	×		×	×	Gold
85994	Brown Hill Extended .	×			×	
85995	,, ,,	×			×	Tourmaline.
85996	Hannan's Brown Hill .			×		{ Tourmaline. { Brown-spar.
86000	Hannan's Star . .				×	Gold.
86008	South Kalgurli . .	×		×	×	Magnetite.
86009	,, . .	×		×	×	Fahlerz.

primary gold is present in thicker and more lumpy masses than the finely divided secondary gold.

Fahlerz. This somewhat closely resembles the petzite and coloradoite in appearance; it has the same conchoidal fracture, but the iron-black colour is rather darker and often somewhat dull on the surface. The streak is black; H. = 4. Qualitative analysis showed the presence of copper, sulphur, and arsenic, with rather less antimony and a little iron and zinc. Small patches of the massive mineral were found on four of the telluride specimens.

This is without doubt the same mineral as the copper-ore noted by Dr. Krusch (1901, p. 202, footnote), for which he gives no name, but states that the composition is near that of enargite. From the analysis he gives, I have deduced the fahlerz formula [1]—

$$[3R'_2S \cdot R'''_2S_3] + \tfrac{1}{5}[6R''S \cdot R'''_2S_3].$$

This formula partly accounts for the excess of sulphur, which is, in any case, much less than that required by the enargite formula. The analysis shows the presence of 16·87 per cent. of arsenic and 4·30 per cent. of antimony, so that the mineral is nearer to tennantite than to tetrahedrite.

Magnetite. Three or four crystals, each measuring about a centimetre across, were found embedded in the tellurides on a single specimen from the Kalgurli mine. They are iron-black with a bright metallic lustre, and are strongly magnetic. The small faces present on one crystal were determined on the goniometer to be those of the octahedron and rhombic dodecahedron. The crystals are remarkable in possessing perfect parting-planes parallel to the faces of the octahedron. From the surfaces of parting are often to be seen deep-red flashes of reflected light; and when a piece of the mineral is crushed and examined under the microscope many fragments are seen to be blood-red by transmitted light and to be doubly refracting. The streak of the mineral is dark purplish-brown, but that of the portion of the powder attracted by a magnet is black. In these crystals there has therefore been a partial alteration along the parting-planes of the magnetite to hematite, and they really represent a stage in the formation of *martite*.

Calcite appears to be present on only one specimen, this being a portion of the original material from Hannan's Block 45, discovered by Mr. Holroyd in 1896. It has the character of a white crystalline limestone, in which the calaverite is embedded. *Dolomite*, on the other

[1] Compare this Magazine, 1899, vol. xii, p. 202.

hand, is present on most specimens; it usually forms grey, compact bands interfoliated in the greenish schist. On one specimen are cleavable masses of *brown-spar* (probably mesitite).

Tourmaline occurs as small black needles, 2 to 3 mm. in length, embedded in iron-pyrites and in the rock. It has a specific gravity of about 3·2, and the dichroic colours vary from quite black to nearly colourless. A very little *chalcopyrite* is enclosed in coloradoite on one specimen; on another it is represented by a mere speck in quartz. Veins of fibrous *gypsum* penetrate the altered rock of one specimen.

The matrix[1] of the telluride specimens is usually a pale greenish **sericite-schist** with a silvery reflection, and soft enough to be scratched by the finger-nail. Minute grains and crystals, usually cubes, of *iron-pyrites* are scattered throughout the whole rock. *Chlorite* is also often present, and the rock is then of a darker green colour, and may approach a chlorite-schist in character. Interfoliated with the schist are often bands of grey, granular dolomite, so that at times the rock has rather the character of a calc-schist. Patches of massive, colourless *quartz* and of finely granular iron-pyrites are sometimes present, especially in close association with the tellurides, though not in very large amounts. The tellurides are embedded in the schist as irregular masses of variable size, and often follow joint-planes oblique to the schistosity; the rock appears never to be finely impregnated with tellurides as it is with iron-pyrites.

A more detailed examination was made of the rock of the large specimen (No. 86066). A thin section, perpendicular to the schistosity, showed under the microscope much *sericite* and a considerable amount of quartz. The quartz is present as fairly large, irregular individuals, usually with a more or less marked undulose extinction, and also as patches of mosaic. Much iron-pyrites is present as small grains; only one speck of black telluride was to be seen. There are also many irregular patches of *ilmenite*, which shows well-marked planes of parting and has been largely altered to 'leucoxene.' These small masses of ilmenite give rise to a knotted appearance on the surfaces of foliation as seen in a hand-specimen of the schist. A chemical examination of the

[1] The matrix of the ore is often stated to be hornblende-schist. No hornblende was detected on any of the British Museum specimens; and in published analyses (Simpson, 1902) of these rocks the small amount of magnesia in the portion of the rock insoluble in hydrochloric acid indicates that not much, if any, hornblende can be present. Bands of hornblende-schist are no doubt sometimes present in the sericite-schist. Much confusion between observed fact and theory has been occasioned by the attempts of various authors to explain the origin of these schists.

rock showed the presence of silica, alumina, iron, alkalies (potash and soda), and a little lime; when heated in a bulb-tube it blackens and gives off scarcely any water. The ilmenite was proved to contain iron and titanium, and to be non-magnetic.

The altered rocks from the upper portions of the lodes are soft and clayey and yellow in colour, but they usually still retain their schistose character. Besides *limonite* and the finely divided secondary gold, few other minerals are found in these oxidized ores. On one specimen, from the Golden Horse-Shoe Estates, the 'sponge-gold' is accompanied by a few small colourless rhombohedra of dolomite, and a yellowish-green ochreous substance which is perhaps massicot (PbO)[1].

With the alteration of such large quantities of tellurides one would expect to find other secondary minerals together with the native gold, such, for example, as native silver (from the petzite) and oxygen compounds of tellurium (tellurite (TeO_2), emmonsite, durdenite, &c.), but none of these were detected[2] on the British Museum specimens. Mr. Simpson (1898, p. 46) suggests the occurrence of emmonsite (hydrated ferric tellurite), and Mr. Rickard (1901, p. 712) mentions the presence of tellurite of iron on a specimen from Kalgoorlie. Silver chloride is stated to have been found in considerable quantity near the surface in one of the mines (Pittman, 1898, p. 11).

Other minerals, which have been described as occurring with the Kalgoorlie tellurides, but which were not detected on the British Museum specimens, are native tellurium (Holroyd, 1897; MacIvor, 1900) and roscoelite (Pearce, 1897). Hessite (Schmeisser, 1897, p. 50; Krusch, 1901), amalgam (Pittman, 1898), and native mercury (Rickard, 1901, p. 715) have also been mentioned; and Simpson gives several other names in his lists of minerals, but without particulars.

'Kalgoorlite' and 'Coolgardite.'

'Kalgoorlite' was described by Mr. E. F. Pittman in 1898 as a new mineral species with an iron-black colour and sub-conchoidal fracture, a specific gravity of 8·791, and a chemical composition expressed by the formula $HgAu_2Ag_6Te_6$. The analysis, by Mr. J. C. H. Mingaye, from which this formula was deduced, is quoted below. The material on

[1] A chemical examination showed the presence of much lead, with a little copper and water, and possibly some antimony.

[2] It is possible that some of the yellowish earthy material, taken to be limonite, may contain tellurium in the oxidized state, but none of this was examined chemically.

which the new name was based came from the Lake View and Boulder Junction gold-mine at Kalgoorlie. Recently Mr. E. S. Simpson (1902) states that in 'a sample from the Ivanhoe Mine' he found gold 19·4, silver 30·1 per cent.

'Coolgardite' was based by Professor Adolphe Carnot in 1901 on the results of three analyses, from which he deduced the formula $(Au,Ag,Hg,Cu,Fe,Sb)_2Te_3$, or more simply $(Au,Ag,Hg)_2Te_3$; the new mineral being defined as a sesquitelluride of gold, silver, and mercury. The material he examined was supplied for analysis by Mr. A. G. Holroyd from the Western Australian exhibits at the Paris Exhibition of 1900; it consisted of fragments, isolated from the matrix and contained in six tubes, all of which, with the exception of one tube of sylvanite, were labelled as being from the Great Boulder Proprietary gold-mine at Kalgoorlie. Professor Carnot remarks that the material contained in each tube was not always the same in appearance and colour, but adds that he took the precaution of separating the different kinds when the quantity of material available for analysis permitted. He further remarks that the material contained in each tube may have been taken from different specimens. In addition to 'coolgardite' he made analyses, quoted above, of sylvanite, calaverite, and petzite.

Two analyses (Nos. 1 and 2 in the following table) of 'coolgardite' were made on material belonging to the same lot. This is described as only exceptionally showing indications of cleavage, the fracture being almost always conchoidal: the colour of the different fragments was iron-grey, or yellowish-grey inclining to bronze; separate analyses were therefore made of two fragments. Another analysis (No. 3) was made on a sample of material described as yellowish-grey with a conchoidal fracture.

	Te.	Au.	Ag.	Hg.	Cu.			Total.
'Kalgoorlite'	[37.26]	20.72	30.98	10.86	0.05; S, 0.13.			100.00
						Fe.	Sb.	
'Coolgardite' (1)	56.55	23.15	16.65	3.10	0.10	trace	0.20	99.75
" (2)	53.70	27.75	13.60	3.70	0.25	trace	0.15	99.15
" (3)	51.13	37.06	4.71	3.70	0.88	0.90	1.20	99.58

That 'kalgoorlite' is not a homogeneous mineral, but a mixture, has already been suggested by Mr. T. A. Rickard (1901, p. 715), who with reference to it remarks: 'As the crystallographic features [i. e. external characters] do not differ materially from coloradoite, it can hardly be considered as more than an impure variety of the latter, and may be looked

upon as a mixture of petzite and coloradoite.' Again, Professor Carnot applies the name 'kalgoorlite' to a 'mercurial petzite,' of which he gives three analyses (quoted above, under petzite); the 'kalgoorlite' of Carnot is, however, considerably different in composition from the 'kalgoorlite' of Pittman, and this adds support to Rickard's suggestion.

A fact that strikes one as being specially remarkable is that neither Mr. Pittman nor Professor Carnot, both of whom describe more than one kind of telluride, makes any mention of coloradoite. This telluride of mercury is, as noted above, of frequent occurrence at Kalgoorlie, and, furthermore, had been found there before the descriptions of 'kalgoorlite' and 'coolgardite' were published: it was recognized by Mr. T. A. Rickard in 1897, and in the same year a specimen showing calaverite and coloradoite was represented in the British Museum collection. This is a point of special importance, since it is impossible to distinguish between coloradoite and petzite by their appearance alone. It would be extremely difficult, if not impossible, to collect pure material for analysis from a mixture of these two minerals, even when it is known that both are present; and in case the presence of coloradoite was not suspected, and not tested for, it would of course be quite overlooked. It is therefore highly probable that the mercury shown in the analyses of 'kalgoorlite' and 'coolgardite' was due to the presence of coloradoite.

Even a study of the original papers themselves suggests that 'kalgoorlite' and 'coolgardite' cannot be distinct mineral species. A massive mineral, which in a single analysis gives, like 'kalgoorlite,' an unusual and complex formula, has, in most cases, little claim to rank as a distinct species, and absolutely none when its composition can be just as well, or even better, explained on the assumption that the material analysed was a mixture of known minerals. Mineralogical literature is unfortunately heavily burdened with numerous imperfectly and incompletely determined 'new species' of this kind.

The formula of 'kalgoorlite' may be split up as follows:—

$$\underset{\text{('Kalgoorlite')}}{HgAu_2Ag_6Te_6} = \underset{\text{(Coloradoite)}}{HgTe} + \underset{\text{(Petzite)}}{2Ag_3AuTe_2} + Te.$$

The atomic ratio, 3 : 1, of silver to gold is exactly that given by all analyses of petzite. The excess of tellurium scarcely needs explanation, since this element was not determined directly in the analysis, but only by difference.

The wide variations in the three analyses of 'coolgardite' are in themselves enough to suggest that the material analysed was not homogeneous;

and this impression is amply supported by the brief description Professor Carnot gives of the external characters of his material. As pointed out above (p. 273), the material used in three other of Carnot's analyses was very probably not homogeneous, and in one case this is even admitted by Carnot himself. A point which is perhaps in favour of the existence of 'coolgardite' is the fact that the results obtained in three separate analyses can, on the assumption of isomorphous mixing, be all made to agree more or less closely with one general formula: the calculated[1] atomic ratios of (Au,Ag,Hg) : Te are 1 : 1·551, 1 : 1·483, and 1 : 1·610 in the three analyses respectively.

The empirical formulae corresponding to Carnot's analyses are :—

(1) $HgAg_{10}Au_{7.6}Te_{28.8}$.
(2) $HgAg_{6.8}Au_{7.6}Te_{22.9}$.
(3) $HgAg_{2.4}Au_{10.2}Te_{21.8}$.

These, by solving simultaneous equations, may be split up as follows :—

(1) $HgTe + 1{\cdot}23\,Ag_3AuTe_2 + 0{\cdot}07\,AuTe_2 + 6{\cdot}3\,AuAgTe_4$.
(2) $HgTe + 1{\cdot}15\,Ag_3AuTe_2 + 3{\cdot}1\,AuTe_2 + 3{\cdot}35\,AuAgTe_4$.
(3) $HgTe + 0{\cdot}73\,Ag_3AuTe_2 + 9{\cdot}27\,AuTe_2 + 0{\cdot}2\,AuAgTe_4$.
(Coloradoite) (Petzite) (Calaverite) (Sylvanite)

The third analysis would thus appear to have been made on material consisting mainly of calaverite; and this is in agreement with Carnot's statement that the material was yellowish-grey with a conchoidal fracture. In the first two analyses more of the iron-black tellurides and more sylvanite would be present, and in No. 1 practically no calaverite; this, again, is in agreement with Carnot's statement of the external characters of the material, which he describes as varying in colour from iron-grey to yellowish-grey, and usually with a conchoidal fracture, but sometimes a cleavage. Although not stated by Carnot, it would appear that analysis No. 2 was made on a yellower fragment. The difference in colour is explained by Carnot as due to the difference in the relative proportions of gold and silver shown in the analyses, but this is scarcely likely to be the case. Of special importance is the fact that Carnot made no serious attempt to separate the black from the yellow, for, as he distinctly states in his paper, he simply took for each analysis

[1] The small amounts of antimony, copper, and iron, calculated by Carnot with the metals, are here neglected, as it seems doubtful whether the antimony should be taken with the tellurium or with the gold; it is not unlikely that they are impurities due to the presence of fahlerz. The atomic weights used here and elsewhere in the present paper are those recommended in 1901 by the Atomic-Weight Commission of the German Chemical Society.

(Nos. 1 and 2) only *one* piece of material. It would be extremely unlikely, under the circumstances, for such material to be pure and all of one kind.

I have been informed by Mr. F. T. Trouton, the assistant curator of the Western Australian exhibits at Paris, &c., that the material supplied to Professor Carnot for analysis consisted of fragments which had become detached from various specimens. It is thus not unlikely that some of Carnot's material was actually from specimens now in the British Museum. I have myself collected such a tube of fragments, which, owing to the extremely friable nature of the tellurides, have become detached during the transportation and handling of the specimens. From such a collection of fragments of all kinds and from several specimens it would not be at all easy to collect material suitable for analysis. The sylvanite, if coarsely crystallized, could no doubt be easily picked out, but not so easily calaverite from coloradoite and petzite; these are sometimes associated together in the same fragment, and it is only with difficulty that the actual junction of the calaverite with the iron-black mineral can be detected, while the coloradoite and petzite are absolutely indistinguishable.

Although I have had some experience in collecting pure material for analysis, I should be unwilling to deal with such a sample. On this occasion I have given (p. 276 above) more fully the method I adopt for collecting opaque minerals[1] for analysis. Whenever possible, however, only crystals are taken, and these are broken up and each fragment collected separately; and in cases where there can be any possible doubt as to the identity of the mineral, every crystal or crystal fragment is measured on the goniometer. All this of course takes time, and the collection of even less than a gram of material may mean several weeks' work, but it is the only way by which errors are to be avoided. Even with all care and precaution the material may be rendered impure by the presence of an unsuspected mineral, as was undoubtedly the case with coloradoite in 'kalgoorlite' and 'coolgardite.' An exactly similar case has occurred with the material collected by myself for analyses of stannite[2]. On the results of these analyses, especially together with the remarkable development of the crystals, there could have been based a far more plausible 'new mineral' than either 'kalgoorlite' or 'coolgardite.' The analytical results could, however, be explained on

[1] e. g. andorite, argyrodite, fahlerz, plagionite, &c., described in the pages of this Magazine.

[2] This volume, p. 61.

the assumption that the material used was a mixture of stannite and andorite, and on again examining the part of the specimen from which the material had been collected, this was amply confirmed.

With the object of testing whether these doubts as to the existence of 'kalgoorlite' and 'coolgardite' have really any ground, I have made a detailed examination of all the British Museum specimens of Western Australian tellurides. Although I have not had an opportunity of examining the original material on which the names were based, yet, as noted above, a large amount of the available material came from the same source as did that examined by Professor Carnot, and, indeed, possibly from the same specimens.

Five specimens have at various times been received at the Museum labelled as 'kalgoorlite,' but on whose authority was not stated. On none of these was anything found which answered (except in external characters) to the description of 'kalgoorlite.' On two specimens the only telluride to be found was coloradoite; on another calaverite and coloradoite; on a fourth calaverite and petzite; while on one specimen calaverite, coloradoite, and petzite were all detected, but no other telluride.

The material was examined before the blowpipe in the manner described above. When any mercury was given off in the bulb-tube the mineral was in all cases completely decomposed with the formation of metallic mercury and tellurous oxide; while, when no mercury was given off in the tube, the same fragment afterwards gave a metallic bead on charcoal. Numerous fragments when first heated on the charcoal completely volatilized without leaving the slightest residue. All these fragments were therefore either mercury telluride or gold and silver telluride, and none could have contained all three metals as required by 'kalgoorlite' and 'coolgardite.' These tests, which are reliable and also quickly and readily performed, were made use of for the purpose of distinguishing between the iron-black minerals with conchoidal fracture, namely, coloradoite, petzite (and fahlerz), and also to detect if possible the presence of any 'kalgoorlite' and 'coolgardite.' The fragments tested were detached from the specimens by a needle, and each examined under a lens; only quite small fragments showing the conchoidal fracture uninterruptedly over the whole surface were selected.

In this way 133 fragments[1] of the iron-black tellurides taken from

[1] This includes twenty-one fragments examined to test the purity of the material collected for the qualitative analyses of coloradoite. Of the 112 fragments taken at haphazard, thirty-four were petzite and seventy-eight coloradoite; this gives an idea of the relative frequency of occurrence of these two tellurides.

different portions of thirty-five specimens were separately examined; of these, thirty-four were found to be petzite and the remainder coloradoite. In addition to these, about thirty fragments of calaverite and sylvanite were examined before the blowpipe. On the forty-eight specimens examined, more than one kind of telluride was found on twenty-five; calaverite and coloradoite were found together on seventeen, and petzite and coloradoite on seven (see table, p. 279).

Petzite and coloradoite being indistinguishable in external appearance, it is possible to take fragments in which both these tellurides are present, and which are to all appearance homogeneous; such fragments will of course be found to contain gold, silver, and mercury, and will thus answer perfectly to the description of 'kalgoorlite.' On these larger fragments, however, the conchoidal fracture was not continuous over the whole surface, indicating that the fragment consisted of more than one crystalline individual of the same kind of mineral, or even (as is actually the case) of different minerals. When, however, small fragments with a continuous conchoidal fracture were taken they were found in *every* case to be either coloradoite or petzite, containing either no gold or no mercury.

After this fairly exhaustive search for 'kalgoorlite,' one is perfectly justified in assuming that no such mineral exists, especially when the single analysis on which the name is based can be simply explained by the intermixture of the two minerals, petzite and coloradoite, which in external appearance are indistinguishable, and which have been shown to actually occur intimately associated together at Kalgoorlie.

While the cause of the error in the case of 'kalgoorlite' is readily explained, it is less easy to believe that such an error could have been committed in the case of 'coolgardite'; for there are marked differences in the external characters of the iron-black tellurides (petzite and coloradoite) and the light-coloured tellurides (calaverite and sylvanite), which must have been present in the mixtures analysed. Professor Carnot indeed notices these differences, but makes no mention of the possibility of the material being a mixture.

There appears to be little to support Professor Carnot's supposition that mercury is capable of isomorphously replacing gold and silver, beyond the fact that these metals, like so many others, crystallize in the cubic system. And it might be suggested that 'coolgardite' is a mixture of coloradoite and a hitherto unknown sesquitelluride of gold and silver, $(Au,Ag)_2Te_3$, as given by Carnot's formula. The ratio (Au,Ag) : Te is then 1 : 1·640, 1 : 1·586, and 1 : 1·739 in the three analyses respectively.

The excess over 1 : 1·5 could then be readily explained by the admixture of small amounts of the known tellurides, calaverite and sylvanite. This view receives some support from the fact that, on the assumption of a mixture of known tellurides as here adopted, there must have been four different tellurides present in the material used for analysis No. 2[1]. On none of the British Museum specimens were more than three different kinds of tellurides found associated together, and it thus seems unlikely, but not impossible, that there should have been three or four kinds in a single fragment such as is stated by Carnot to have been used in two (Nos. 1 and 2) of his analyses. On the other hand, if several fragments from the miscellaneous sample had been used for analysis, as may have been the case in analysis No. 3, there is less objection to the assumption of a mixture of four different tellurides. Again, in the mixtures suggested above, the amount of sylvanite seems to be excessive; this, however, would be less if the calaverite were assumed to contain some silver, or if hessite be present (cf. pp. 274, 282). The probable existence of an intimate mixture of sylvanite and petzite has been noted above (foot of p. 275).

There thus appears, on the whole, to be no more evidence for the existence of a mineral having the composition $(Au,Ag)_2Te_3$ than for minerals with the compositions $(Au,Ag)_3Te_3$ and $(Au,Ag)_4Te_3$ (see p. 273); and it seems best, for the present at least, to assume that in all these cases the material used for analysis consisted of mixtures of known tellurides.

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[1] The small amount of calaverite in No. 1 is negligible; and in No. 3 there would be no sylvanite if the calaverite contained even a little silver.

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Notes on minerals from the neighbourhood of Binn (Switzerland)—Mispickel, Pyrites, Diopside, and Quartz.

By W. J. Lewis, M.A.

Professor of Mineralogy in the University of Cambridge.

[Read November 18, 1902.]

Mispickel.

CRYSTALS of mispickel are occasionally found in long brilliant tin-white prisms of simple habit in the cavities of the dolomite at Lengenbach, near Binn; but they are more frequent as isolated crystals entirely imbedded in a rather compact mass of the dolomite. The crystals are elongated in the direction of the brachy-axis, and are terminated by two minute faces which give good images and prove to be the faces usually adopted as the prism {110}. The long faces are much striated parallel to their mutual edges of intersection; and the images were consequently so elongated in this zone that only roughly approximate measurements of the angles could be obtained. The brachydomes satisfactorily established were s {012} and l {011}. On a very minute needle the faces of {021} seem to be associated with s{012}, but the angles over homologous edges in which these faces meet the adjacent faces s differed by as much as 3°. One crystal seemed to be an elbow-twin with (110) for twin-face, but the angles were not measured.

The angles on which reliance could be placed were on one crystal, $mm' = 68° 50'$, $ll' = 100° 45'$: on a second very minute crystal, $mm' = 68° 50{\cdot}5'$, $ms = 72° 44'$—$73° 27'$, $ss' = 61° 40'$—$62° 34'$. The angles adopted to give the elements are: $mm' = 68° 52{\cdot}5'$, $ms = 72° 55'$; hence $ss' = 62° 36'$ and $ll' = 101° 8'$.

On referring to Miller's table of angles in his edition of Phillips' 'Mineralogy,' 1852, it will be found that his three angular elements are (1) not consistent with one another, and (2) do not accord with the angles given in his table. Miller's two angular elements, $D = 29° 41'$, and $E = 49° 56'$, agree with those adopted by Professor Dana, whilst the third is given as $F = 55° 56{\cdot}5'$ instead of $55° 52{\cdot}5'$ as is required by the relation $\tan D \tan E \tan F = 1$.

Again, in the table we are given $mm' = 68° 48'$, $ll' = 100° 38'$, and $ee' = 120° 48'$; whilst the two angular elements first given above require

mm' to be 68° 15′, ll' to be 99° 52′, and ee' 120° 38′. The three angles given are consistent; for tan 34° 24′ tan 60° 24′ = cot D = tan 50° 19′. It looks therefore as if Miller had computed his table from the given angles, and had then in error copied his elements from another sheet of paper on which other elements had been tried.

Pyrites.

On the crystals of this substance from the Binn dolomite numerous faces are sometimes observed. On one of the crystals measured the following forms were determined: a {100}, $e = \pi$ {210} bright, π {120} rough and ill-developed, o {111}, μ {411}, m {311}, n {211}, β {322}, {544}, $s = \pi$ {321}.

The angles measured were:

o : (544)	6° 8′ and 6° 45′
$o\beta$	11 25
on	19 28
om	29 27, 29° 7′ and 28° 49′
$o\mu$	35 12
oa	54 43
os	22 21 and 22° 31′
oe	39 7

Diopside.

Some good crystals of diopside of a pistachio-green colour imbedded in quartz are stated to be from mount Cherbadung, and doubtless come from the locality described in Hintze's 'Mineralogie,' vol. ii, p. 1063, as Thierälpeli, Tscherwandune. The crystals are sometimes long rectangular prisms with edges modified and several terminal faces; sometimes the prisms are short and not much larger than some of the faces at the ends. The angles measured accord very closely with those given by vom Rath for augite from Vesuvius. The forms which were observed are: {100}, {310}, {210}, {110}, {130}, {010}, {10$\bar{1}$}, {111}, {221}, {021}, {$\bar{2}$21}, {$\bar{3}$12}, and {$\bar{1}$32}. The faces were for the most part bright and gave very fair images; but the faces of {10$\bar{1}$}, {$\bar{3}$12}, {$\bar{1}$32} were dull, and had much the aspect of a face artificially ground but not polished.

Pericline, Quartz, and Sphene.

In September, 1901, a mineral-seeker from Binn found in the rocks on the south side of the Ofenhorn a cavity which was lined with large

crystals of pericline and quartz. With considerable labour these were extracted in large specimens, two of which weighed approximately 1 cwt. and $\frac{1}{2}$ cwt. respectively; the larger one is now in the British Museum, the smaller one at Cambridge. The crystals of pericline are of much the usual habit, and are much twinned according to the pericline-law. The faces are bright, but so deeply striated that I have not discovered any crystals which admit of goniometric measurement.

The crystals of quartz are limpid, but occasionally penetrated by and incrusted with chlorite. They are unusually rich in faces which belong more especially to direct rhombohedra and trapezohedra. As observed by Des Cloizeaux in his 'Mémoire sur la cristallisation et la structure intérieure du quartz,' 1858, the faces of the direct forms are bright, fairly free from striae, and slightly rounded; those of the inverse forms are small and much striated. The faces r $\{100\}$ and z $\{\bar{1}22\}$ are fairly large and irregularly developed.

The direct rhombohedra observed are: $\{100\}$, $\{13.\bar{2}.\bar{2}\}$, $\{7\bar{2}\bar{2}\}$, $\{3\bar{1}\bar{1}\}$, $\{31.\bar{1}\bar{1}.\bar{1}\bar{1}\}$, $\{11.\bar{4}.\bar{4}\}$, $\{5\bar{2}\bar{2}\}$, $\{17.\bar{7}.\bar{7}\}$, $\{7\bar{3}\bar{3}\}$, and possibly $\{29.\bar{1}\bar{0}.\bar{1}\bar{0}\}$, $\{9\bar{4}\bar{4}\}$.

The inverse rhombohedra are: $\{\bar{1}22\}$, $\{\bar{7}55\}$, $\{\bar{3}22\}$, but the measurements from which the two last symbols were derived were not very trustworthy.

The direct trapezohedra are: u $\{8\bar{4}\bar{1}\}$, y $\{10.\bar{5}.\bar{2}\}$, x $\{4\bar{2}\bar{1}\}$. On two crystals a well-defined image was obtained between those of x and y inclined at 53° 26′ and 53° 42′ respectively to z: this face may be either $(22.\bar{1}\bar{1}.\bar{5})$, or $(14.7.\bar{3})$. The former makes with z an angle 53° 41·5′, the latter one of 53° 11·5′.

The inverse trapezohedra are: t $\{11.\bar{4}.2\}$, μ $\{2\bar{2}1\}$, $\{8.\bar{1}\bar{0}.5\}$.

The trigonal bipyramid s $\{4\bar{2}1\}$ is also present on most of the crystals, and is striated in a direction parallel to the edges in which it meets faces of the inverse trapezohedra.

The prism faces $\{2\bar{1}\bar{1}\}$ are usually of considerable length, and the crystals are sometimes doubly terminated.

The crystals of sphene are of the chlorine-green colour common to those which come from the Central Alps, and many of them are twins with (100) for twin-face. Adopting Des Cloizeaux's and Dana's axial system, the forms observed are: $\{100\}$, $\{102\}$, $\{001\}$, $\{111\}$, $\{021\}$, $\{310\}$, $\{110\}$, $\{\bar{1}32\}$, $\{\bar{1}12\}$. There was nothing exceptional in the crystals or the angles.

On some new forms prominently developed on crystals of Proustite.

By F. E. E. Lamplough,

Of Trinity College, Cambridge.

[Communicated by Professor W. J. Lewis, and read November 18, 1902.]

WHILST determining some crystals of proustite in the Mineralogical Museum at Cambridge, and which came from Bolivia or some other part of South America, my attention was attracted by faces of trigonal pyramids, which, as shown in figs. 1 and 2, are the most conspicuous on the crystals. On measurement, these faces were found to correspond very nearly to those of the rhombohedra $\{7\bar{3}\bar{3}\} = 10\,R$ (fig. 1) and $\{9\bar{4}\bar{4}\} = 13\,R$ (fig. 2). The figures represent with fair accuracy the

Fig. 1.

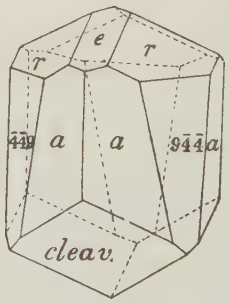

Fig. 2.

Proustite.

relatively large development of the faces of these new forms. Another form, $\{11.\bar{7}.\bar{7}\} = -6\,R$, represented by a single face on the lower end of one crystal, is also new for proustite. Ten crystals were measured, and, among these, seven showed the following forms:—

(1) $r\,\{100\}$, $a\,\{10\bar{1}\}$, $v\,\{20\bar{1}\}$, $\{7\bar{3}\bar{3}\}$. (2) r, a, $e\,\{110\}$, v, $\{7\bar{3}\bar{3}\}$. (3) a, e, $\{9\bar{4}\bar{4}\}$. (5) a, e, $\{9\bar{4}\bar{4}\}$. (7) r, a, e, $\{9\bar{4}\bar{4}\}$. (9) r, e, $\{9\bar{4}\bar{4}\}$. (10) r, e, a, $\{9\bar{4}\bar{4}\}$, $\{11.\bar{7}.\bar{7}\}$.

The appended table gives the measurements obtained for the several

crystals, together with the computed angles[1]. The theoretical value of the angle v : (7$\bar{3}$3$\bar{3}$) was calculated by the formula given by Professor Lewis in his memoir on Grassmann's method[2].

	Crystal 1.	Crystal 2.	Crystal 3.	Crystal 5.	Crystal 7.	Crystal 9.	Crystal 10.	Observed Means.	No. of Observations.	Computed Angle.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′
(9$\bar{4}\bar{4}$) : r	...	...	...	...	...	42 30	42 18 42 55	42 34	3	42 24
(7$\bar{3}\bar{3}$) : r	40 49½ 40 24½ 40 43	40 27 40 35	...	...	...	...	...	40 36	5	40 59
(11.7.7) : r	...	...	...	...	...	...	57 21	57 21	1	57 18·5
re	...	67 44 67 59	...	...	...	67 29	67 36 67 29	67 39½	5	67 46
(9$\bar{4}\bar{4}$) : e	...	...	109 51	110 18	110 2	109 59	109 54 110 24	110 5	6	110 10
ar	...	...	...	...	53 52	...	54 11	54 1	2	53 54
av	24 53	...	...	...	...	...	...	24 53	1	24 34
ae''	...	...	...	...	90 17	...	...	90 17	1	90 0
vr	29 6½ 29 25	...	...	...	...	...	...	29 16	2	29 20
rr'	72 11	...	...	...	...	...	71 55	72 3	2	72 12
re''	...	...	...	...	35 59	...	35 59 35 56	35 58	3	36 6
ae	...	...	69 20 or 67 59 68 41	68 20	...	...	...	68 30	2	68 37
ee'	...	...	43 5 42 43	43 0	...	...	...	42 56	3	42 46
(7$\bar{3}\bar{3}$) : v	24 18 24 20	...	...	...	...	...	...	24 19	2	24 27·5
(7$\bar{3}\bar{3}$) : a	...	30 22	...	...	...	...	...	30 22	1	30 34
(7$\bar{3}\bar{3}$) : (3$\bar{3}$7)	118 34	...	...	...	...	...	...	118 34	1	118 52
(9$\bar{4}\bar{4}$) : (101)	...	...	73 28	73 8	73 25	...	...	73 21½	1	73 28

[1] From the element of Prof. Miers, this Magazine, 1888, vol. viii, p. 44.

[2] This Magazine, 1900, vol. xii, p. 339.

Crystalline forms of Carbides and Silicides of Iron and Manganese ('Ferro-manganese,' &c.).

By L. J. Spencer, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read November 18, 1902.]

Mallard[1], in 1879, noted that crystals of the metallurgical products 'Spiegeleisen' and 'ferro-manganese' are of two kinds. Both show a prism-zone of six faces, but when the percentage of manganese reaches a certain amount there is an abrupt change in the habit of the crystals and in the angles between their faces. Crystals containing from 11 up to 52 or 55 per cent. of manganese are lamellar, and were found to have a prism-angle ($mm''' = 110 : 1\bar{1}0$) of 67° 27′, while crystals containing a larger amount of manganese are acicular and have a pseudo-hexagonal prism-zone, the angular measurements of which varied between 58° 42′ and 61° 20′.

These observations have been confirmed by Rathke[2] and Brauns. Crystals with the composition given by the analysis quoted below under (1) were found to have a prism-angle[3] of 68° 5′, while crystals with more manganese, as shown in analysis (2), had angles of about 60° in the prism-zone.

	Fe.	Mn.	C.	Si.	P.
(1)	47·93	44·99	6·48	0·52	0·00
(2)	9·48	82·45	7·47	0·18	0·10

These differences in crystalline form are in correspondence with the metallurgical terms 'Spiegeleisen' and 'ferro-manganese'; the former

[1] E. Mallard, Sur la forme cristalline du ferromanganèse. Bull. Soc. Min. de France, 1878, vol. ii, pp. 47–50.

[2] B. Rathke, Ueber krystallisirtes Ferromangan. Liebig's Annalen der Chemie, 1890, vol. cclx, pp. 326–32. [With crystallographic determinations by R. Brauns.]

[3] This angle, 68° 5′, is the mean of readings which varied between 67° 40′ and 68° 30′. It is given by Brauns as the angle *bm*, since it was repeated four times on the same crystal; this repetition may, however, be explained by twinning on a prism-plane.

has a lamellar crystalline structure and contains less manganese, while the latter has an acicular structure and more manganese.

The absence of terminal faces has prevented previous observers from completely determining the crystals, and it has thus been impossible to state to which crystal-system they belong.

Crystals of two kinds, with prism-angles the same as noted above, and with well-developed terminations, have recently been sent to the British Museum for crystallographic determination by Mr. J. E. Stead, the well-known metallographer. In these crystals, however, the carbon is largely replaced by silicon, but their composition is expressed by the same general formula, $(Fe,Mn)_3(C,Si)$, as is that of ordinary 'ferro-manganese.' In the hope of elucidating the differences in crystalline form and chemical composition presented by this group of substances, other samples of material have been sent by Mr. Stead for crystallographic examination, but unfortunately none of the crystals on these show any definite terminal faces. Besides the material supplied by Mr. Stead, two other specimens, from French iron-furnaces and previously in the British Museum, were examined. I have to express my thanks to Mr. Stead for kindly supplying most of the material for examination, and also for his permission to publish separately the crystallographic results.

The physical characters are much the same in all the seven samples examined. The crystals are of a steel-grey colour, but are often tarnished bronze-yellow; unless covered with a dull, black crust, they have a brilliant metallic lustre. They are very brittle, and have a hardness on Mohs' scale of $6\frac{1}{2}$. They are non-magnetic.

The crystallographic characters of each sample, as far as could be determined, are separately described below under Nos. I to VII. For various reasons, such as the dullness, striation, or repetition of the faces, or the divergent grouping of the crystals, accurate measurements could be obtained only exceptionally. Nevertheless, by measurement of the crystals the different samples could be divided into two sharply defined groups:

(*a*) Crystals showing a rhombic prism-zone with a prism-angle of about $67\frac{1}{2}°$ ($mm''' = 67\frac{1}{2}°$, $bm = 56\frac{1}{4}°$). Terminated crystals (on sample No. I) belong to the orthorhombic system.

(*b*) Crystals showing a pseudo-hexagonal prism-zone with angles varying between 59° and 61°. Terminated crystals (on sample No. IV) belong to the anorthic system.

Carbo-silicide of Manganese and Iron.

I. This material, from the hearth of a blast-furnace at Blaina, Monmouthshire, has already been described in detail by Mr. Stead[1], and the original mass of crystals described and figured has been generously presented by him to the British Museum. Since then, Mr. E. Poulaine, the general manager of the Blaina Works, has presented to the Museum a finer specimen with much larger crystals, these reaching up to $4\frac{1}{2}$ cm. in length and 1 cm. in thickness. This larger specimen, however, shows nothing essentially different from the specimen already described, and I simply quote my crystallographic results from Mr. Stead's paper.

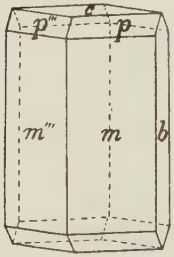

Fig. 1.—Carbo-silicide of manganese and iron.

Crystal class: holohedral-orthorhombic.

Forms: $m\{110\}$, $p\{111\}$, $c\{001\}$, $b\{010\}$.

The faces of the crystals (fig. 1) are dull and drusy, and do not give any reflected image of the goniometer-signal. The mean of several readings taken in the position of maximum illumination gave the following approximate values for the angles:—

$$cp\,(001 : 111) = 51°,\ mm'''\,(110 : 1\bar{1}0) = 66°.$$

The corresponding axial ratios are:—

$$a : b : c = 0{\cdot}65 : 1 : 0{\cdot}67.$$

Carbide of Iron and Manganese ('Spiegeleisen').

II. More exact measurements in the prism-zone were obtained with crystals from a French iron-furnace. The specimen consists of a friable, cellular aggregate of blade-shaped and acicular crystals, which reach up to 10 cm. in length. The crystals, when not broken, have ragged terminations consisting of fine points, and no definite terminal faces could be found.

Measurement of four crystals, both blades and needles, showed that there is a rhombic prism-zone with the forms $m\{110\}$ and $b\{010\}$. The best crystal, from four of the faces of which single, sharp images were reflected, gave

$$mm'''\,(110 : 1\bar{1}0) = 67°\,32'\ \text{and}\ mb\,(110 : 010) = 56°\,14'.$$

[1] J. E. Stead, Crystals of carbo-silicide of manganese and iron. Journ. Iron and Steel Institute, 1901, No. 1, vol. lix, pp. 79–88. Here fig. 2 incorrectly represents the crystals as orthorhombic with inclined hemihedrism.

The crystals are deeply striated parallel to the length of the prism, and are often quite thin and blade-shaped parallel to the brachypinacoid, $b\{010\}$.

III. This sample shows smaller crystals of the same character as No. II thickly lining the walls of a cavity in compact material. No really good measurements were obtained; the means of all readings from five crystals are:—

$$mm''' = 67° 33' \text{ (limits, } 66\tfrac{1}{2}° - 68\tfrac{1}{4}°).$$
$$mb \quad = 56° 12' \text{ („ } \quad 55\tfrac{1}{2}° - 56° 49').$$

The order in which these angles were repeated on one crystal suggested that it was twinned on a prism-plane.

From the above measurements (Nos. II and III) crystals of 'Spiegeleisen' may belong to either the orthorhombic or the oblique system; the agreement in the prism-angle with that of the carbo-silicide (No. I) makes it very probable, however, that the system is orthorhombic, and that the carbide and carbo-silicide are isomorphous.

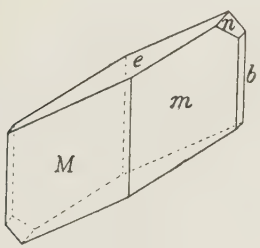

Fig. 2.

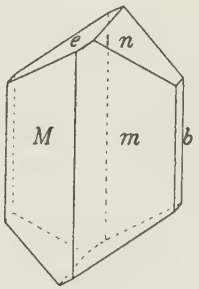

Fig. 3.

Silicide of iron and manganese.

Silicide of Iron and Manganese ('Silico-ferro-manganese').

IV. The small and somewhat indistinct crystals line cavities in the crystalline material. The faces of the crystals are rather uneven and have the character of ground glass, but they sometimes give definite reflections; the measurements are therefore only approximate.

Crystal class: holohedral-anorthic.

Elements: $a : b : c = 0{\cdot}58 : 1 : 0{\cdot}66$; $\alpha = 85° 12'$, $\beta = 97° 43'$, $\gamma = 90° 39'$.

Forms: $m\{110\}$, $M\{1\bar{1}0\}$, $b\{010\}$, $n\{011\}$, $e\{0\bar{1}1\}$.

The usual habit of the crystals is illustrated in fig. 2; often n and b

are quite small or absent, and the crystals then closely resemble acute rhombohedra. On one crystal the faces n and those in the prism-zone are more largely developed, as shown in fig. 3. Figs. 2 and 3 represent the actual crystals, each about 1 mm. across, which were measured on the goniometer.

	Measured.	Mean.	Calculated.
bm, 010 : 110	58°–61½°	60° about	—
mM, 110 : 1$\bar{1}$0		,,	—
Mb', 1$\bar{1}$0 : 0$\bar{1}$0		,,	60° 0′
bn, 010 : 011	60° 16′, 60°	60° 8′	60 0
ne, 011 : 0$\bar{1}$1	66 42, 66 37′	66 39	—
eb', 0$\bar{1}$1 : 0$\bar{1}$0	53 13, 53½	53 21	—
nm, 011 : 110	69 29, 69	69 15	69 28
nM', 011 : $\bar{1}$10	81 19, 81½	81 25	—
eM, 0$\bar{1}$1 : 1$\bar{1}$0	66 8, 66 40, 67¼°	66 41	66 56
em', 0$\bar{1}$1 : $\bar{1}$1$\bar{1}$0	78 8, 77, 78	77 43	78 10

Carbide of Manganese and Iron ('Ferro-manganese').

V. This sample is almost pure carbide of manganese with very little iron. It is a compact aggregate of acicular crystals arranged approximately parallel to each other; in small interspaces, bright crystal-faces are developed. The six faces in the prism-zone are of about equal size, and are striated parallel to their mutual intersections. Six crystals were measured, and two or three very good readings obtained, the best being 59° 46′ and 60° 16′ (on the same crystal), while others varied between 59° 22′ and 59° 50′, and between 60° 15′ and 60° 29′. None of the crystals had good faces all round the zone, and no symmetrical or definite repetition of the angles could be detected; it is therefore probable that the crystals are twinned on a prism-plane, as is frequently the case with pseudo-hexagonal crystals.

VI. A friable, cellular network of acicular crystals confusedly arranged. Measurements in the prism-zone varied between 59° and 61°. On one crystal was noticed a rough terminal plane at about 90° to the prism.

VII. A confused aggregate of small needles, much intergrown, in a cavity of compact material. The best angles obtained from five crystals were 59° 34′ and 60° 23′; but again no definite order in the occurrence of the angles around the zone could be traced.

The measurements from samples Nos. V–VII, like those of Mallard and

Brauns, are insufficient to decide whether the crystals of 'ferro-manganese' belong to the orthorhombic, oblique, or anorthic system; but the occurrence of a similar pseudo-hexagonal zone on the anorthic crystals of 'silico-ferro-manganese' (No. IV) suggests that 'ferro-manganese' may also be anorthic, and that the two are isomorphous. It is to be noted, however, that neither the silicide nor the carbo-silicide follow Mallard's rule as to the relation between the size of the prism-angle and the amount of manganese present. It is possible that the difference in crystalline form does not depend on the amount of manganese, but that we have here an isodimorphous series. The present observations are thus still insufficient to determine the inter-relations of this group of substances, and more measurements from terminated crystals are required.

The following analyses, made in Mr. Stead's laboratory, give, under the corresponding numbers, the chemical composition of the material examined crystallographically. All agree fairly closely with the general formula $(Fe,Mn)_3(C,Si)$.

	Fe.	Mn.	C.	Si.	Prism-angle.
I.	34·80	56·80	3·90	3·31	66° about
II.	59·35 60·00	32·50 33·40	6·08 5·85	0·37 0·23	67° 32′
III.	48·10	44·05	6·40	1·35	67 33
IV [1].	67·40	20·10	1·63	10·50	60° about
V.	very little	—	—	very little	,,
VI [2].	29·80	61·98	6·83	0·26	,,
VII.	—	80	—	very little	,,

Crystals of 'silico-ferro-manganese,' from furnaces at Nijni-Tagilsk in the Urals, have been measured by Eremyeev [3], who found them to belong to the cubic system with the forms {102} and {100}, but distorted so as to simulate orthorhombic symmetry. These crystals are therefore quite distinct from those described above, but as Eremyeev does not give their chemical composition the two kinds cannot be further compared.

The meteoric mineral cohenite, $(Fe,Ni,Co)_3C$, has been proved by

[1] Of massive material, not of crystals. Also P, 0·17; S, trace.

[2] A small amount of graphite was detected between the crystals.

[3] Verhandl. russ.-kais. mineral. Gesell. St. Petersburg, 1879, ser. 2, vol. xiv, p. 246. A German abstract of this note is given in Zeits. Kryst. Min., 1879, vol. iii, p. 438, under the title: P. von Jeremejew. Krystalle des Ferromangansiliciums.

Hussak[1] to crystallize in the cubic system. This carbide of iron usually contains 2 or 3 per cent. of nickel and cobalt, but smaller amounts were found by Cohen[2] in the cohenite of terrestrial irons from Greenland. It is therefore probable, as pointed out by Groth[3], that the carbide of iron, Fe_3C, which is a constituent of steel and to which the name cementite has been given, is identical with cohenite.

The carbide (Fe_3C) and silicides (Fe_2Si, Fe_3Si_2, FeSi, and $FeSi_2$) of iron prepared in recent years by Moissan and other chemists, although frequently crystallized, do not appear to have been submitted to crystallographic examination.

[1] Archivos do Museu Nacional do Rio de Janeiro, 1896, vol. ix, pp. 130, 160.

[2] Meddelelser om Grønland, 1897, vol. xv, p. 293; Ann. k. k. naturhist. Hofmuseums, Wien, 1897, vol. xii, p. 58.

[3] Tabellar. Uebersicht der Mineralien, 4th edit., p. 16. Braunschweig, 1898.

NOTES.

We regret to record the deaths of the following mineralogists:—

Dr. Antonio D'Achiardi (1839–1902), Professor of Mineralogy in the University of Pisa. He was the author of numerous papers and textbooks, including a mineralogy of Tuscany, and only a short time ago was elected an honorary member of this Society.

M. Augustin Alexis Damour (1808-1902), who, after his retirement from the diplomatic service in 1854, devoted himself to the chemical study of minerals.

Dr. Friedrich August Frenzel (1842–1902), who advanced from the position of a working miner to that of Director of the Royal Metallurgical Laboratory at Freiberg (Saxony); his talent was recognized by Breithaupt. He was the author of numerous mineralogical papers written since 1870, his well-known 'Mineralogisches Lexicon für das Königreich Sachsen' having been published in 1874.

Professor Paul Gabriel Hautefeuille (1836–1902), member of the Paris Academy of Sciences and Professor of Mineralogy in the University of Paris. He was successful in the artificial preparation of numerous minerals.

M. Vivant Léon Moissenet (1831–1901), formerly Professor of Assaying in the École des Mines, Paris, and an honorary member of this Society since 1877; he was the author of several papers on the mineral-veins of Cornwall.

Dr. Carlo Riva (1872–1902), Docent in Petrology and assistant in the Mineralogical Laboratory of the University of Pavia; his early death was the result of an accident in the Alps.

The Rev. Dr. Thomas Wiltshire (1826–1902), formerly Professor of Geology and Mineralogy in King's College, London, and a member of this Society. His collection of minerals he gave, a few years ago, to the Mineralogical Museum at Cambridge.

An effort is being made by the mayor and municipal council of St. Just-en-Chaussée, dép. Oise, to raise a memorial to two famous men, the brothers Haüy, who were born at that town: René Just (1743–1822), abbé and mineralogist, was the founder of mineralogy as an exact science; Valentin (1746–1822), philanthropist, was the founder of the

first school for the blind. The French and English mineralogical societies are interesting themselves in the appeal for subscription, and it is to be hoped that the sum of 25,000 francs required to carry out the project will soon be raised.

To the extensive donations of Mr. J. Pierpont Morgan to public mineral collections, noted in the last number of this Magazine, must now be added that of a collection of precious stones recently presented by him to the Muséum d'Histoire Naturelle at Paris. This collection, consisting of 600 specimens of facetted and rough stones, was brought together by Mr. G. F. Kunz for the Pan-American Exposition of 1901 to illustrate the occurrence of precious stones in both North and South America, and especially in the United States, and is said to be one of the finest and most complete collections of its kind.

Among the several exhibits of mineralogical interest at the Royal Society's Conversazione in May last may be mentioned the microscope preparations of meteoric and artificial irons shown by Mr. J. E. Stead. When polished surfaces are heated in air the various constituents—metallic iron, carbide and phosphide of iron—acquire different oxidization tints, which in reflected light rival in brilliancy the polarization colours of a transparent mineral section. In this way was shown the minute structure of a piece of artificial iron in which small, but beautifully marked, Widmanstätten figures had been developed by the very slow cooling of the mass from a high temperature.

It is interesting to remember that this method of 'heat-tinting' was the way by which the crystalline structure of meteoric iron was shown by Widmanstätten in 1808. The method has, however, been recently developed by metallographers, and, in conjunction with Koenigsberger's method of detecting polarization of light reflected from the surfaces of opaque crystals (abstract, this vol., p. 203), should find an extensive application in the study of meteoric irons.

The rare event of the fall of a meteoric stone was witnessed on September 13, 1902, near Crumlin in co. Antrim. The weight of the stone is 9 lb. $5\frac{1}{2}$ oz., and it measures $7\frac{1}{2} \times 6\frac{1}{2} \times 3\frac{1}{2}$ inches; it is thus the largest stone which has been observed to fall in the British Isles for eighty-nine years. The stone was acquired for the British Museum collection through Mr. Fletcher, who has given a preliminary account of the fall and of the stone itself in 'Nature' (vol. lxvi, p. 577).

In addition to the Crumlin meteorite, mentioned above, the following noteworthy recent additions to the mineral collection of the British Museum may be mentioned:—

A large crystal of topaz, measuring two feet in length and weighing 137 pounds, from Sætersdalen, Norway.

A large and valuable collection of native gold and gold tellurides from Western Australia, presented by the Government of Western Australia and by various gold-mining companies. A description of these specimens is given above on p. 268, and a selection of them is exhibited in the recent acquisition case in the Mineral Gallery.

We have received several descriptive catalogues and guides reprinted from the Report of the United States National Museum at Washington. One of these, by Mr. George P. Merrill, on the non-metallic minerals exhibited in the section of Applied Geology, extends to 330 pages and is illustrated by 30 excellent plates together with several text-figures, and is in itself a valuable text-book on the economic applications of minerals. Other catalogues, by Mr. Wirt Tassin, deal with the collection of precious stones (200 pp., 9 plates and 26 text-figures), the collection of meteorites, and a collection illustrating the properties of minerals, while another outlines the classification adopted for the systematic collection of minerals.

From the annual report for 1889–1900 we learn that the same museum has acquired the private collection of minerals of the late Professor C. U. Shepard; this includes some 5,000 selected specimens, many of them types described by Professor Shepard and of great rarity.

A small handbook, 'Aids to the Analysis and Assay of Ores, Metals, Fuels, &c.,' by J. James Morgan (London, 1902, viii + 105 pp. Price 2*s.* 6*d.*, or in paper covers 2*s.*), has been received from the publishers, Baillière, Tindall & Cox. It gives concise instructions for the execution of various technical analyses.

ABSTRACTS.

On the Use of the Stereographic Projection for Geographical Maps and Sailing Charts (S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiii, pp. 245–75, 347–76).

On the Solution of Problems in Crystallography by means of Graphical Methods, based upon Spherical and Plane Trigonometry (S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, pp. 249–84).

These papers arise from and are particular developments of an earlier paper by the author, 'The Stereographic Projection and its Possibilities, from a Graphical Standpoint' (Amer. Journ. Sci., 1901, ser. 4, vol. xi, pp. 1–24, 115–44.—Abstract, this vol., p. 203). Both open with a brief explanation of this projection and of the employment of the protractors devised by the author.

In the first paper the author proceeds to explain clearly how a map should be constructed on these principles, and how from it the distances between any two points shown thereon may be accurately determined. The important question of distortion is discussed, and shown to be very small up to about 70° from the centre, and not very great even up to 90°. The large stereographic map of the United States, a reduced copy of which is shown, is treated in detail. Examples of measurements between various towns by means of a scale of miles are given and compared with the values obtained from calculation or measured on a polyconic map. Even without applying some easy corrections the measurements on the stereographic map are wonderfully accurate and greatly superior to those made on a polyconic map. In the application to navigation the superiority of this projection for great-circle sailing is made obvious. The author concludes his paper by protesting against the inaccurate maps and scales obtaining in almost all school atlases and geographies.

In the second paper the author employs the projection for the graphical determination from observation of the fundamental constants and indices of the faces. Examples of crystals belonging to each of the six systems are worked out in detail. The author in conclusion lays stress on the advantages of these methods both as a check on the accuracy of computation and as a means of grasping the principles underlying the mathematical formulae. G. F. H. S.

Simpler Methods in Crystallography (J. G. Goodchild, Proc. Roy. Phys. Soc. Edinburgh, 1901, vol. xiv, pp. 323–59; 1902, vol. xiv, pp. 403–34).—The author describes methods for the construction of

projections from the fundamental constants and indices of the faces. The methods do not depend on the angles between faces and involve no knowledge of plane or spherical trigonometry. The author discusses the gnomonic and stereographic projections for the different systems, treating the case of anorthic crystals at some length. He proceeds to show how the indices of faces may be determined from the observed zonal relations with the help of a stereogram. He adds a method for drawing crystals in the clinographic position, and gives a practical rule for obtaining the axial cross required, showing how it must be modified for systems other than the cubic. G. F. H. S.

Crystalline form of Geikielite (P. von Sustschinsky, Zeits. Kryst. Min., 1902, vol. xxxvii, pp. 57–62).—An examination of new material, brought from Rakwana, Ceylon, by Dr. Grünling (abstract, this vol., p. 93), has led to the determination of the crystalline form of geikielite, a point which was left undecided in the original description of this mineral (this Magazine, vol. x, p. 145). The material cleaves parallel to the faces of a rhombohedron of $94°7'$; one cleavage is good, another poor, while the third was only obtained after several trials. [This would indicate planes of parting rather than true cleavage.] The basal plane is represented by crystal-faces and by planes of parting. On one small and rather indistinct crystal were faces belonging to the forms $c\{111\}$, ϕ $\{611\}$, and perhaps $\{\bar{1}11\}$, but no cleavage was observed. The measured value of the cleavage angle, rr' $(100 : 010) = 94°7'$, corresponds to the axial ratio $a : c = 1 : 1{\cdot}370$.

Analyses agree with the formula $MgTiO_3$, but show a small excess of ferric oxide. The sp. gr. of the material is 3·976. The small rounded masses of geikielite are sometimes embedded in laterite, which also contains small grains of quartz and grains and octahedra of colourless spinel. Rutile is intergrown with the geikielite. L. J. S.

Chemical Composition of Xenotime (E. H. Kraus and J. Reitinger, Zeits. Kryst. Min., 1901, vol. xxxiv, pp. 268–77).—The xenotime of Dattas near Diamantina in Brazil, analysed by Gorceix in 1886, is shown by a new analysis (I) not to be an orthophosphate, but a sulphatophosphate of the rare earths with the formula $3R_2O_3{\cdot}3P_2O_5{\cdot}SO_3$: the new name, *hussakite*, is given to it because of this difference in chemical composition. The mineral occurs, in a perfectly fresh condition, in sands as long prismatic crystals which are transparent and of a yellow to brown colour: the cleavage, interfacial angles, and other characters are the same as for ordinary xenotime; sp. gr. 4·507.

	SO_3	P_2O_5	Y_2O_3	Er_2O_3	Gd_2O_3	Fe_2O_3	Al_2O_3	CaO	MgO	Total.
I.	6·13	33·51	43·43	14·82	1·99	0·20	traces			100·08
II.	2·68	27·37	45·86	13·67	0·42	4·54	1·16	2·56	0·45	99·70

Analysis II (contains also: SiO_2, 0·62; H_2O, 0·37 per cent.) is of pyramidal crystals of cloudy, opaque xenotime from sands at Bandeira de Mello, Bahia, Brazil. This appears to be intermediate between xenotime and hussakite. Sulphuric anhydride was also detected in slightly altered xenotime from Hitterö, but not in the much altered xenotime of other Norwegian localities. It thus appears that hussakite is liable to alteration, the sulphuric anhydride being extracted, and that ordinary xenotime is really a pseudomorph after hussakite. This is supported by the fact that sulphuric anhydride is easily extracted from powdered hussakite by digestion with soda solution.

[The authors have made the important observation that the chemical composition of xenotime has been previously incorrectly determined, but they do not appear, on this account, to be justified in giving a new name, which, if done in other similar cases, would lead to an unnecessary multiplication of mineral names.] L. J. S.

A new Cadmium Mineral (E. Wittich and B. Neumann, Centralblatt Min., 1901, pp. 549–51; and Chemiker-Zeitung, 1901, vol. xxv, pp. 561–2).—The new mineral, cadmium oxide, CdO, was found as a black shining incrustation, and as powder, on a mass of ferruginous zinc silicate from Monte Poni, Sardinia. The minute crystals are regular octahedra, sometimes with cube planes, and resemble the artificial crystals obtained when cadmium is burnt in oxygen.

Although small quantities of cadmium are of fairly wide distribution in zinc minerals, yet the only cadmium mineral previously known is greenockite (CdS). L. J. S.

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